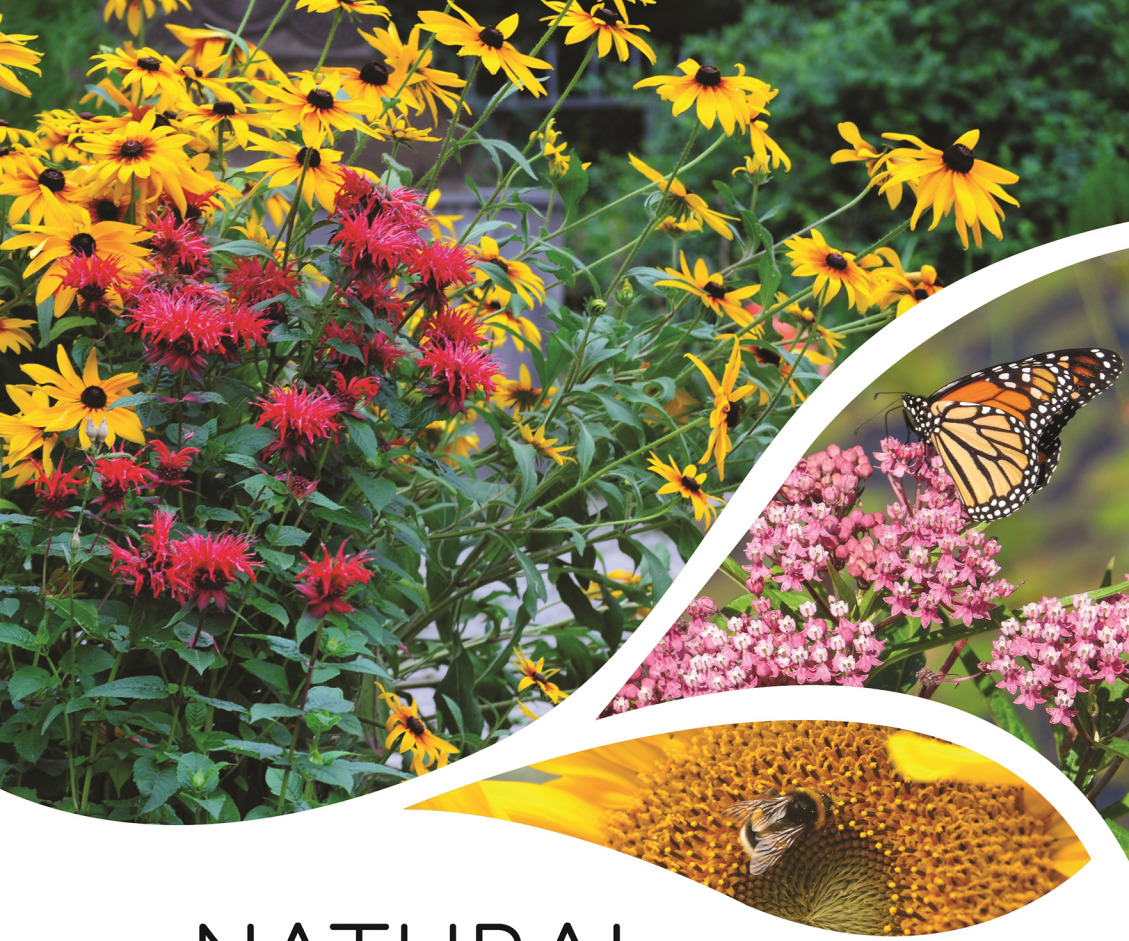

NATURAL HABITATS & WILDLIFE GARDENING

INVITING NATURE INTO YOUR BACKYARD

SHAUN McCOSHUM

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Princeton University Press
Princeton and Oxford

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Published by Princeton University Press
41 William Street, Princeton, New Jersey 08540
99 Banbury Road, Oxford OX2 6JX

press.princeton.edu

GPSR Authorized Representative: Easy Access System Europe - Mustamäe tee 50, 10621 Tallinn, Estonia, gpsr.requests@easproject.com

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ISBN 9780691261003
ISBN (e-book) 9780691261010

Library of Congress Control Number 2025945889

British Library Cataloging-in-Publication Data is available

Editorial: Robert Kirk and Megan Mendonça
Production Editorial: Ali Parrington
Cover Design: Wanda España
Publicity: Matthew Taylor and Caitlyn Robson-Iszatt
Copyeditor: Patricia Fogarty
Typesetting and Design: D & N Publishing, Wiltshire, UK
Cover Images: Shutterstock

This book has been composed in Adobe Caslon Pro (main text) and Interpol Sans (headings)

Printed in China

10 9 8 7 6 5 4 3 2 1

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FOREWORD

Welcome to *Natural Habitats and Wildlife Gardening: Inviting Nature into Your Backyard*. The ideas and concepts presented here are intended to educate readers about ecological processes, ecosystems, key resources for wildlife, and ways to build robust habitats by replicating natural processes. Over the past century and a half, devastating changes have occurred throughout North America, reducing habitat for most species of animals and plants. Data continue to show plummeting populations, with over a 66% decline in abundance for a wide variety of animals since 1920. Many gardeners are trying to do their part to help wildlife by planting native plants and encouraging insect populations. However, native plants mostly provide food for animals and do not meet the characteristics of specific resources for summer shelters and winter refugia. Plants that host resources like hollow tree cavities can take decades to mature and even more time for hollows to form. In an area that is only planted with early-succession seeds and starters, as often seen in pollinator plantings, and that also fails to address the missing resources, it would take decades for crucial shelters to form naturally through succession and ecosystem engineers. Gardens and landscapes around human developments almost never allow succession to occur and regularly remove needed shelters, so creating robust habitat must include shelters, food, and water that fit species' specific needs.

Throughout this book, examples are provided to further illustrate concepts and offer ideas to implement in landscapes. Some examples are repeated because readers may skip

A colorful wildflower garden tucked away on private property. Plantings like this usually aim to mimic natural meadows or prairies for pollinators.

sections or not want to refer back to topics. Chapter 1 explains some of the major natural phenomena and critical roles some wildlife have in creating habitats. How to replicate habitats and mimic important actions of wildlife are discussed in chapter 2. Concepts are then applied to animals throughout chapter 3, which covers wildlife grouped by higher taxonomic groups as well as the needs of specific species, along with ways to encourage their populations. Further applications are presented in chapter 4, along with clarifications for a few common garden initiatives and practices like Leave the Leaves.

Although many ideas are discussed within the limits of common laws and local ordinances, this book is not a legal reference nor a structural guide. Always check with federal, state, county, and city laws, local ordinances, and other governing documents and agencies before starting a project. Similarly, make sure projects are structurally sound and up to local codes, and call local services to mark utilities and underground infrastructure before digging.

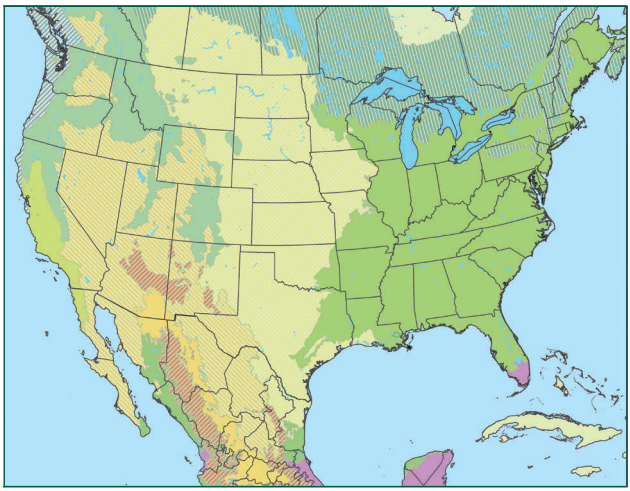
Photographs were taken by Loren Merrill and Leslie Miller, with supplemental pictures and illustrations made by the author. Happy gardening!

A cottage-style garden with native plants from south Texas that includes many habitat enhancements that are discussed in this book. (A) Underground shelter and burrow. (B) Crevice shelters and vertical soil access. (C) Mowed, pesticide-free path. (D) Leaf mulch from nearby oak tree covering organic-rich soil pocket mimicking succession. (E) Sandy soils for bee nesting covering the underground shelter. (F) Hydration stations (left: ground level; right: raised). (G) Stacked rocks with gaps, soil layers, and cavities. (H) Slow compost pile tucked behind shrubs. (I) Woody material including log border and tree-stump pedestal supporting the raised water feature.

NATURAL ECOSYSTEMS, HABITAT SUCCESSION, AND MAJOR CHANGES

Ecosystems and Habitat Composition

In North America, ecologists and botanists have grouped vegetation communities and climatic variables into ecoregions. The broadest groupings are known as ecoregions Level I, and they are: Arctic Cordillera, Eastern Temperate Forests, Great Plains, Hudson Plain, Marine West Coast Forest, Mediterranean California, North American Deserts, Northern Forests, Northwestern Forested Mountains, Southern



EPA 2018f. Ecoregions of North America, Environmental Protection Agency, Tigerline

North America can be described by major plant communities known as ecoregions. Here Level I, the most general level, has 15 ecoregions.

Semiarid Highlands, Taiga, Temperate Sierras, Tropical Dry Forests, Tropical Wet Forests, and Tundra. Each Level I ecoregion is further divided into Level II (50 regions) and Level III (182 regions). The conterminous United States, or lower 48, are further divided into Level IV ecoregions. Large, detailed maps are available through the United States Environmental Protection Agency website. Take the time to familiarize yourself with the most detailed level for your area. Make sure to note which plant communities existed in your region prior to development and which plants were most abundant. These details are in the description for each ecoregion. For dense urban areas, integrating once-dominant native plants is crucial in rebuilding native habitats. In most habitats, the dominant vegetation also provides important food sources for many animals and hosts shelter. Adding these plant species back to the landscape dilutes the developed, non-native matrix, which allows wildlife to move back into these areas.

Within each ecoregion, habitats and ecosystems are linked by the organisms, biotic interactions, as well as the abiotic, or non-living, characteristics of the region. Within each ecosystem, different types of habitats exist that can have distinct boundaries, like a pond shore, or have a more blended transition, like a savannah and grassland. The term *habitat* can be applied in a few different ways. One use categorizes

In this managed landscape, home to American Bison (*Bison bison*) and many other megafauna, a variety of habitats are present: living forests, post-burn wood stands, meadows, grasslands, and riparian areas. Over time, these vegetation communities move due to disturbances and succession.

areas by a characteristic—sunlight exposure, water presence, dominant plant growth form (tree, shrub, herbaceous), and so on. Descriptions like this can cover large or small areas. For example, a forest habitat can describe a group of trees or hundreds of square miles. People also use *habitat* to mean a group of features or an overall area with the particular needs of a species. A prime instance for this use is "good fish habitat" for areas in a lake or river, but the term can also be applied to a very small space, like under a decaying log. The broad use and meaning of the word *habitat* can lead to some confusion, so it is important to pay attention to the intended meaning and get clarification in conversations. In this book, *habitat* will be used with different meanings, but the use will be further explained to clarify what is meant.

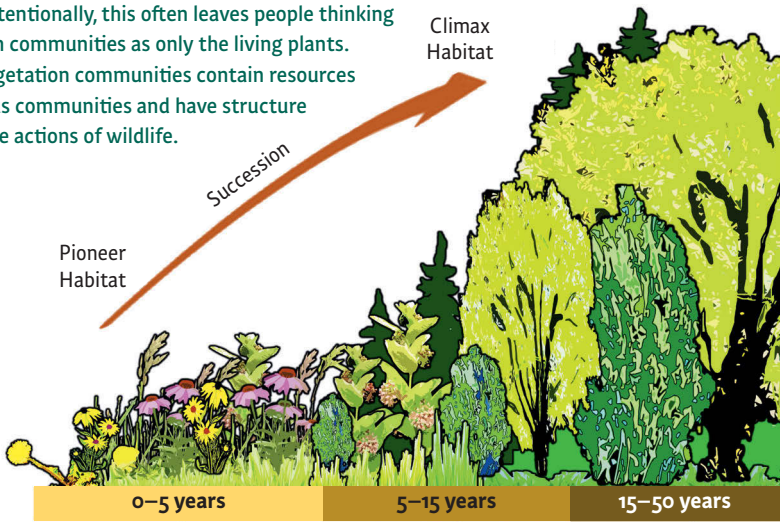
In contrast, ecoregions are defined by large-scale abiotic factors, such as rain, winter temperatures, fire, flooding, etc., as well as plant communities. Ecologically speaking, terrestrial habitats are defined by their plant communities, which can make it difficult to understand the importance many animals have in feedback systems that create and maintain most plant communities. If we only consider the living plants, we miss other non-living, small-scale factors such as dead plant material, soil, or rock structure. Although each of these aspects is important, it is the synergy of abiotic

A landscape view of a marshy habitat, which sits within the Northern Forests ecoregion and hosts many microhabitats. Wildlife living in this landscape have access to a variety of resources that can be provided in garden designs as well.

factors and the species that live in a vegetation community that truly defines large-scale and small-scale habitats. Each habitat is a part of the local ecosystem, which over time experiences change, succession, and disturbance.

Vegetation and habitat succession take place in every ecoregion, except the Arctic Cordillera. Most high school science courses teach a very basic model that shows plant community succession. Generally, models start with annual "pioneer" plants on the left and proceeds through big, mature trees on the right. Models like these create two learning pitfalls, however. The first is the fact that non-living plant resources are left out, and the second is the failure to capture the cyclical nature of habitats in ecosystems. Even so, they are a good starting point. "Early-succession" vegetation communities are mostly comprised of fast-growing annuals, biennials, and even some perennials. However, the mix of species that grows after a large disturbance depends on the ecoregion and the event. For example, fires and seasonal floods often quickly increase nutrient availability, so plants that colonize an area (from both the seed bank and dispersal) do well with high nutrients. In comparison, a flood from a beaver dam, a severe drought, or a pest outbreak generally leads to a slower change in nutrient availability, so plants that do well with fewer nutrients successfully grow in these conditions. No matter how the disturbance event changes nutrient availability, early-succession plant communities

Succession models are regularly taught with some variation of this diagram. They explain that areas are colonized by annuals, which then allow perennial herbaceous plants to establish. Over time, shrublands form, then give way to forests, which are labeled the *climax community*; the whole process starts over when a major catastrophe occurs. Unintentionally, this often leaves people thinking of vegetation communities as only the living plants. In reality, vegetation communities contain resources from previous communities and have structure caused by the actions of wildlife.

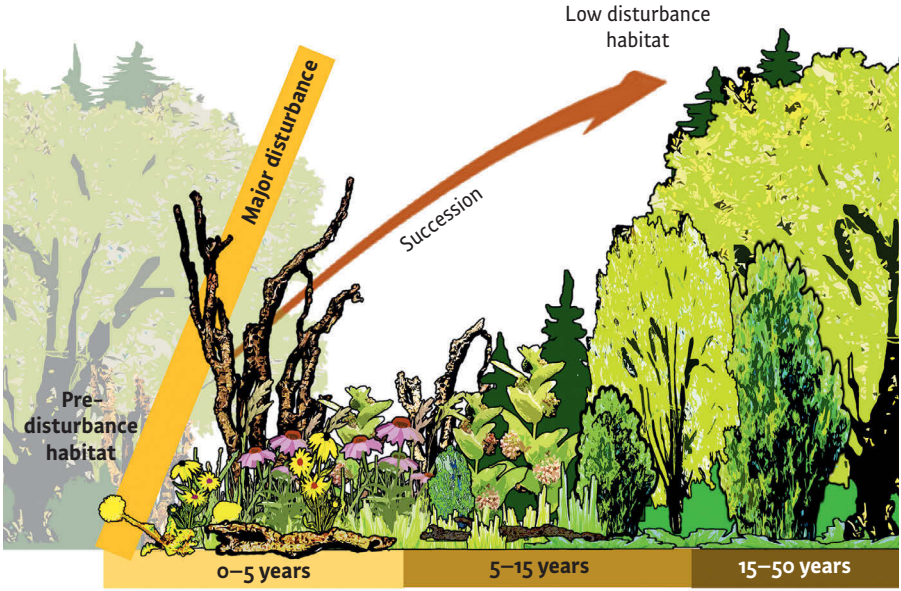


and the wildlife that live in them create microclimates and nutrient cycles that other plant species can survive in. These new microclimates and plants develop into the next plant community supporting different species of wildlife. As those plants grow, they create new conditions that other plants and wildlife can take advantage of—and this repeats until the "climax community" is reached or a new disturbance event occurs. This is depicted in the Updated Habitat Model and Desert Succession Example shown later in this chapter. As each new plant species arrives, new habitat resources are created—from hollow stems to shaded soils—creating a variety of habitat resources for wildlife.

For areas with mature forests, quite a few things can happen that lead to the loss of plants that make up the "climax forest community." As the trees die, the lack of foliage allows sunlight to reach the soils and quickly turns the vegetation community into an "early-succession" plant community. In ecoregions without forests, climax communities are composed of long-lived perennials, typically with large, underground stems or low-growing, woody aerial stems. These non-forested climax communities form in a similar way as the forest communities. Early-succession plants create microclimates, which allows new species to grow, creating new microclimates, and so on, until the climax community is reached.

Looking at each of these habitats, it is easy to focus on the living plants, especially when a person wants to restore an area. However, a vegetation community or plant community is not the same thing as a habitat, even though these terms are often used as synonyms. When discussing a plant community, the habitat includes the

Dense populations of flowering plants establish after a deep burn kills the young forest. Many animal species, including pollinating insects, depend on the scorched wood for nesting sites. Gardeners often plant the flowers for wildlife, but forget to include the woody resources animals depend on.



Here is an update to the common model which adds accuracy because it shows the cyclical patterns of vegetation communities and includes key resources left out of basic models. However, even this model fails to include the disturbances and structures wildlife create.

living plants (vegetation community) as well as the dead vegetation, soil structure, elevation changes, wood, rocks, water, and often some of the animals. We can build on the basic succession model to include the non-flower resources often created by the living plants in the previous community. Including these resources in addition to plants makes it is easier for restoration ecologists and gardeners to understand the large-scale habitats they are restoring and not just the vegetation community. Understanding an area as a habitat can also help piece information together. For example, many organizations have produced plant lists for pollinators, claiming those plants make great pollinator habitat. As noted earlier, these lists can have incorrectly synonymized plant communities and habitats. More importantly, the plants on these lists mainly provide food and ignore the necessary non-plant resources that animals need to carry out their life cycles, including places to nest, pupate, and overwinter. When viewing gardens from the perspective of habitat for a species, rather than a plant list, it is easier to identify resources that are missing from the habitat, which may include wood or soils for nesting and overwintering, places to bathe and lie in the sun, and absent food resources.

Habitat succession is critical for nutrient cycles, soil health, and wildlife populations. As habitats shift throughout the landscape, organisms must establish in new

Herbaceous plant community establishing post-fire in a young forest. Designing a garden to mimic this habitat requires inclusion of wood, wood cavities, and pockets of organic-rich soils. See chapter 2 section "Wood" for more.

habitats and leave the areas that no longer support their populations. Similarly, some habitats become overrun by predators for certain species, which leads to local extirpation. Once a species is locally absent, the natural enemies (predators, parasites, and parasitoids) that specialize on them also disappear or disperse. Significantly fewer natural enemies in an area opens the habitat for new establishment of extirpated prey species, leading to overall population cycles. This change in presence over time leads to the movement of populations, which can facilitate the reduction of parasite loads as healthier organisms are able to travel farther than their sick counterparts. When a species finds a habitat that is not currently occupied, there tend to be fewer predators, an absence of specialist natural enemies, and ample food, allowing quick establishment and population growth. Once a species is established, the natural enemies of that species can then establish and continue the cycle.

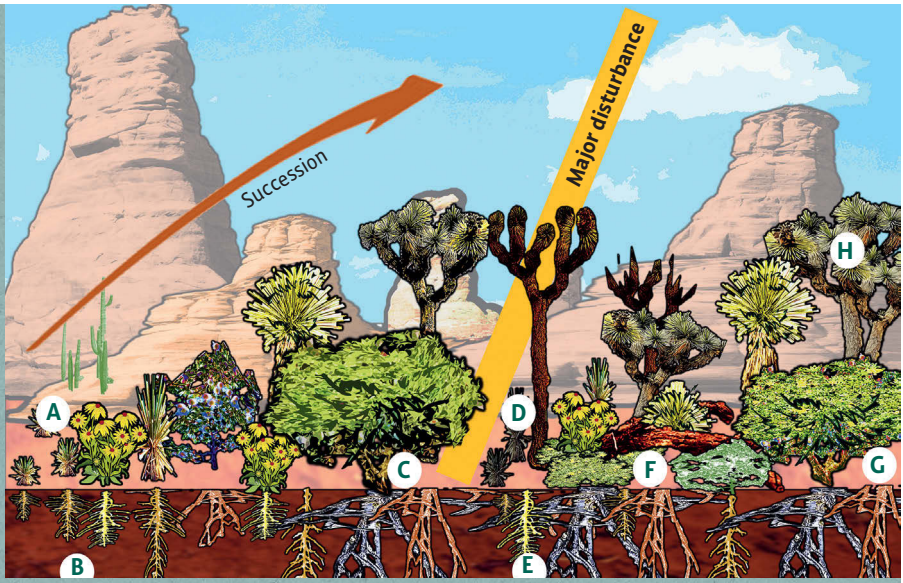
In North America, habitat succession is often prevented in managed landscapes, except for silviculture and managed forests. Managed forests and silviculture create less structural and biological diversity compared to historical patterns and therefore do not support robust, natural communities. Prevention of habitat succession is most severe in our developed areas, gardens, and managed natural areas. Some examples, including city lands, roadsides, and empty lots, are regularly mowed to prevent shrubs and trees from growing, whereas most gardens are weeded to prevent new plants from establishing. At this time, we do not know all of the problems that may result, but data are showing some overall issues. Suspending plant succession allows for soil depletion, loss of key resources for wildlife, the buildup of natural enemies, and overall habitat degradation. As we learn more about populations in managed landscapes and habitats in their natural state, we are developing new methods for management.

DESERT SUCCESSION

Succession models tend to focus on forested areas, which can make them hard to apply to more arid and semi-arid regions, which are found in almost a third of North America. Arid and semi-arid regions, including grasslands and deserts, also experience cyclical plant community succession. In a similar fashion to forested regions, plant materials and habitat changes created by growing plants play important roles in plant succession after disturbances. This includes woody materials aboveground, like yucca trunks and bush branches, as well as an incredible amount of underground biomass of perennial root and stem systems. Many long-lived plants in these regions have the ability to regrow from underground stems or root crowns and are thus commonly known as "fire-adapted." This characteristic allows woody plants like Creosote Bush (*Larrea tridentata*) and Honey Mesquite (*Neltuma glandulosa*) to quickly re-establish aerial vegetation after disturbances like fire and severe drought.

When perennial plants perish, either from a disturbance, competition, or old age, their massive root systems remain. Initially, those roots support soil structure for burrowing animals as well as a suite of bacteria and fungi. As those roots break down, they continue to feed soil microbes, which release nutrients into the soil, feeding other plants, fungi, and insects as well as helping with water retention and permeability. Researchers, including ecologists, have barely begun to understand the underground networks of deserts and arid grasslands. Restoration projects are proving more difficult in drier regions due to the amount of care plants require to establish. Although years with above-average rain are important in perennial plant establishment in arid regions, this process is not very successful in areas with large swaths of cleared lands and soils. This means that gardeners in arid and semi-arid urban areas will likely need to care for native plants for longer periods of time until they can be fully established.

Saguaro cacti (*Carnegiea gigantea*) and desert arroyo landscape with more vegetation structure than plateaus. Succession still occurs in deserts as mature plants die and new seedlings establish.



In deserts as well as grasslands, vegetation communities shift much like in forested ecoregions. However, due to similar plant growth forms and more underground stems, it can be difficult to notice the changes that impact wildlife and microhabitats. (A) Early succession occurs with some perennials and annuals, which are not shown. (B) Perennial plants mature and produce a large amount of underground biomass, which helps them collect water. (C) A mature desert vegetation community with above- and belowground structures creating habitat for organisms within the ecosystem. (D) A major disturbance like fire or extreme drought causes major die-off of aerial vegetation. (E) Underground biomass remains with little die-off. (F) Perennial plants are able to regrow aerial shoots from surviving underground roots and stems, and new plants are also able to establish. (G) A mature desert vegetation community, post-disturbance, with dense underground biomass and varied aboveground vegetation structure. In contrast, areas disturbed by human development remove above- and belowground biomass that leads to mostly barren areas until wet years arrive that allow for perennial plant establishment in the area. (H) Aerial growth from protected meristems. This allows for faster recolonization after disturbances.

Root structures and underground stems create soil structure, break down when plants die, and can often survive fires and droughts. When they decay, large root systems create local depressions and organic-rich pockets that some animals use for nesting and sheltering. A cross-section of eroded soils shows how deep these root systems go.

A large remnant prairie in North Dakota, complete with exposed soils, woody areas, and grasslands. Wildlife gardens are often inspired by these ecosystems, but usually focus on the living plants. Structure and other resources however are critical to include in garden designs.

Pine plantations and other planted lumber production undergo controlled habitat succession but with low plant biodiversity. New practices leave standing snags for birds and wildlife while seedlings mature. Here a pine shrubland in Louisiana is pictured, about four years post-planting.

Although habitat degradation due to lack of succession is rarely discussed, conservationists and habitat managers have been addressing some of the problems to restore areas for wildlife. Soil depletion is often overlooked, but soil scientists are making progress to have conservation plans include soil health. Key resources for wildlife are installed in managed areas to promote specific species. For example, the lack of tall, mature trees with large snags in raptor-conservation areas often have large nest

Conservation work at larger acreages often includes building platforms for nesting birds that would naturally use large stands of dead trees. Here platforms were installed for egrets and herons on Avery Island, in Louisiana, to mimic removed stands of dead trees.

platforms installed. Installation of birdhouses and bee hotels also addresses the lack of snags and wood hollows. Some restoration projects also install resources created by ecosystem engineers during habitat management for specific species. When beavers are absent, wetland complexes, ponds, and dams are created that promote dragonflies, amphibians, and birds. Burrows and caves are installed for Burrowing Owls (*Athene cunicularia*) and tortoises, and the list goes on.

Some of these conservation approaches are regularly used by people creating habitat in smaller areas. Garden centers even offer a number of items for sale specifically

In an open habitat, nest boxes are regularly installed to provide shelter for birds, like this house wren (genus *Troglodytes*). Bird houses are wonderful additions to gardens and mimic natural wood cavities. See chapter 2 section "Wood" for more.

A suburban landscape with resources intentionally added for beauty and wildlife. However, shelters for adult forms are absent. Ensuring resources for the entire life cycles of target species is critical.

for wildlife habitat. There are a variety of amazing books and articles now available that explain the importance of creating habitat, using native plants, and building resources. However, for most urban wildlife species that need shelter, there are no prefab designs available to purchase to enhance areas for them. This text builds on other work and provides a singular source that explains how to evaluate areas for wildlife and create and manage habitats. By understanding how habitats have formed, changed, and moved historically in a natural landscape, we can design better management practices to promote populations. Being aware of how animals, plants, and fungi use resources within habitats also provides a solid basis for evaluating habitats and re-creating areas to keep populations healthy. Ideas presented in this book are pulled from a wide variety of resources, including peer-reviewed research, conservation manuals, and a myriad of books, as well as the author's own data. Application of these ideas focuses on smaller areas, typically in suburban yards, but can be scaled up to large conservation projects as well.

Disturbances and Habitat Succession

While it can be fairly straightforward to understand a cyclical model for succession in an ecosystem, it is important to understand that disturbances do not occur on precise schedules. For example, in the tallgrass prairies of Kansas and Oklahoma, research into historical fire patterns found an average of five years between fires. Many local conservation groups and landowners have grabbed onto that number and are now burning areas every five years. Although this has the desired effect of preventing woody species from maturing and maintaining the grasslands, the natural cycle for

A post-fire landscape with pockets of surviving trees along the stream. Rivers and wetland corridors are natural firebreaks. These areas are refuges for many wildlife and plants that establish again in the landscape post-fire.

the area historically included different disturbance intervals. The average of five years means there is a range of possible years between each fire. So, over the course of a century, a single acre could experience a year with two fires, a few periods with three to five years between burns, or possibly even a decade with no fires—giving a range of years between each fire that would average out to once every five years. Each of those periods, however, would end in a different climax plant community, which affects fire intensity, provides different resources to the post-disturbance habitats, and hosts very different plant and animal communities over the century.

Habitat succession becomes even more nebulous when we include the many different types of disturbances that can occur. In the Eastern Temperate Forests, wooded stands could be killed by flooding from beavers (and the subsequent draining when their dams break), severe fires, droughts, hurricanes, and pest outbreaks. Each of these disturbances would affect all of the plant communities and create shifts to new vegetation communities, leaving behind different resources. This means that a herbaceous plant community growing in an area that was previously forest would support different wildlife than a herbaceous plant community growing in an area that was previously shrubland. Areas that were forests tend to have larger and taller wooden structures compared to shrublands, providing different nesting and foraging habitats. Similarly, the Great Plains have experienced fires, droughts, floods, large seasonal mammal migrations, including American Bison and humans, tornadoes, and vegetation removal by prairie dogs. Each ecosystem historically has a suite of disturbance types that could cause habitat succession or simply maintain the vegetation community; however, these disturbances are often removed, especially in the urban environments where our gardens are located. Developing ways to mimic these

once-common disturbance events, and their overall outcomes, can help improve our urban landscapes for wildlife.

Researchers are still piecing together how all of these abiotic factors affect habitats, as well as how they work together. In addition to the abiotic components, biotic effects (aka wildlife effects) also manipulate systems, which makes it all very nebulous. With each finding, scientists are able to better understand the incredibly entangled causes and effects occurring in the habitats and ecosystems that surround us. Each new caveat gives us new ways to build better neighborhoods, gardens, and wildlife habitats. Sadly, while we have learned more about habitats and natural communities, we have also learned that there is not a single plant community in North America that has avoided human impacts. These impacts include decimated animal populations, especially large mammals, modified rivers and streams, invasive species, pollution of many types, climate change, and urbanization. To better understand the disturbances and their ecological functions, the next section will focus on individual processes.

Ecological Processes and Their Functions

— Fire

Historically, fires were common in many ecoregions of North America, caused by weather events and the people living there. Only in the past 100 years or so has fire suppression and prevention been a leading ecosystem management tool, and it has led to new problems and ecological disasters. Prior to fire suppression, absence of fire as a management tool occurred because Native Americans had their lands stolen, and they were mostly removed from their ancestral lands. This absence of management is rarely noted, but it affects the descriptions of areas by settlers and permeates our understanding of natural, undisturbed systems. For example, settlers described dense flocks of Passenger Pigeons (*Ectopistes migratorius*), which were hunted to extinction. However, European diseases and people were already responsible for hundreds of thousands of deaths of Native Americans. It is theorized that the loss of human life allowed for indigenous agricultural food plots to support an overabundance of Passenger Pigeons (and other wildlife), which led to colonizers observing unnaturally dense flocks. Similarly, as colonizers moved west, they failed to realize that the roads and trails they followed were intentionally managed by Native People's practices, knowledge, and intelligence to support edible plants and traversable landscapes. Native agricultural practices, like clearing vegetation with fire along these trails and throughout habitats, declined with their populations and forced removal, which allowed for dense plant growth that was not previously present but that the Europeans wrote about. These European accounts are often cited as baseline ecological data; however, their writings are rarely corrected for this major shift in the landscape.

When many people think about fire in nature, they conjure images of the worst, most severe forest fires—like, but not limited to, those plaguing the West Coast in summers since the 1990s. However, it is important to understand that there are different severities of disturbance from fire. Researchers in the field of fire science have put together different ways to measure fire and its ecological effects. Ecologically speaking, fire is incredibly interesting and absolutely worth learning about, especially for folks managing large acreages. However, for this book we are going to focus on fire severity as it affects the loss of (or change in) organic matter above and belowground.

Fire severity has five classes: unburned, scorched, light, moderate or severe surface burn, and deep-burning or crown fire. *Unburned* are areas that fire missed, with vegetation unaltered and no clear effects caused by heat from the flames. *Scorched* is when vegetation is affected slightly by the heat, resulting in either lightly toasted or singed leaves. *Light* fire severity is when the tree or shrub canopy is mostly unaffected, while aerial stems and herbaceous vegetation, including surface litter and mosses, can be scorched. The organic layer of the soil and underground stems are largely intact, and charring is limited to a few millimeters deep. *Moderate or severe surface burn* is when all of the understory is charred and scorched; twigs and the organic soil layer have burned up and larger logs have been charred. There is some canopy cover kill, but most survives. Most fire-management approaches aim for this degree of damage to remove fuel loads and retain living perennials. *Deep burn* or *crown fire* is the most severe, with fire killing most plants, including canopy trees. Organic material of all sizes above and within the topsoil layer is also consumed by the fire and replaced by

Herbaceous and shrubland plant community post-fire in North Dakota. Notice the lack of standing vegetation or thatch. This provides better light conditions for seedlings and regrowing perennials. Trimming up yards to clear old stems replicates some roles of fire.

Larkspurs (genus *Delphinium*) and many other meadow-dwelling plants thrive in an area after a deep-burning fire. Gardeners often select these plants to support pollinators and other wildlife but forget to include the wooden snags and other structures with which wildlife coevolved.

white-ash deposition and charred organic matter. Complete canopy kill leads to the succession of a herbaceous plant community around standing snags and charred logs.

In most ecosystems, deep-burning fires were historically rare, mostly because vegetation fuel loads weren't allowed to build up and forests were maintained by the First Peoples living there with light to moderate fires. Even when a deep-burning fire was able to occur, natural features like streams, wetlands, rock ridges, and clearings prevented the fires from burning everything in the local landscape. It is also important to note that many areas in North America were also actively managed by the Peoples living there with light to moderate burns to remove dense understories, create clearings, and keep forests more open than the fire-suppressed forests that are common today. Additionally, environmental degradation, wetland destruction, groundwater depletion that dried springs, and removal of beavers have further compromised natural firebreaks. Weather patterns also have a huge effect on fire severity; e.g., colder temperatures and high humidity suppress the overall heat, the flame height, and the speed at which fires can spread.

Low-intensity fires help reduce fuel loads, or dry vegetation, and release those nutrients quickly, which fertilizes the soil. Moderate fires also do this, while killing some herbaceous plants as well. These fires help maintain grasslands, where many native, pollinator plants evolved as well as many forage plants for large herbivores. In shrublands and forests, these types of fires help open up the understory for shade-tolerant plants to take over, create open space for insects and birds to fly through, while also

Recently harvested silviculture plot with burning piles of limbs and plants not suitable for the mill. Standing trees provide habitat and some shade for establishing seedlings in the following years.

fertilizing the vegetation community. Scientific studies also show that plants become more nutritious for a few years post-fire. In one study, burning transformed low-diversity, sagebrush-dominated communities into relatively high-diversity, grass- and forb-dominated communities that persisted for a decade. Forage biomass and protein content initially increased but then declined to near pre-fire levels after a few years. This also affected herbivore foraging behaviors over the course of the study.

In an urban setting, it would be dangerous (and, in many places, illegal) to use fire as a management tool, but it is easy enough to mimic the effects of fire. Simply

Recently, land managers and agencies have started adopting prescribed burns to manage landscapes. Most often, these burns are to clear out understories and remove woody vegetation from grasslands that prevent habitat succession from occurring.

FIRE

Imaged here is an ecosystem existing a few years post-fire, with living forests, treeless herbaceous communities, shrublands, and herbaceous communities growing between fire-killed trees. Each of the communities affected by the fire hosts different non-plant resources for wildlife. Abiotic factors, such as water availability, sun exposure, and soil, also affected plant colonization and fire severity, which allowed new plant communities to form. Within each plant community there are different habitats and resources for wildlife to use, which affect population abundance and biodiversity.

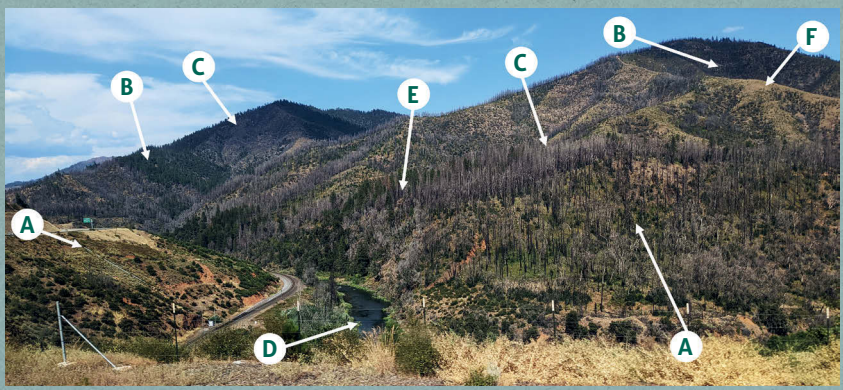


Diagram of heterogeneous landscape that has experienced fires. (A) Recovering shrubland that experienced a light-severity burn. (B) An unburned, forested area the fire did not reach. (C) Crown fire burn that killed trees and now supports a herbaceous plant community among burned snags and fallen logs. (D) Riparian area that did not burn and is a natural firebreak. (E) Moderate burn with some surviving trees and shrubs. (F) Burned herbaceous plant community along a ridge that regularly does not support forest establishment.

removing dead foliage helps seeds germinate and warms the soils. This can be done with powered mowers and weed eaters, or by hand with scythes and clippers. If you are in an area where outdoor fire pits are allowed or have a wood-burning stove, you can also use ashes from chemical-free materials to help fertilize garden beds. Do not use ashes from fire-starter logs, barbecues, or treated woods; they poison the soil with their leftover chemicals.

— Flood

Flooding can be caused by seasonal changes, including snowmelt, increased height of water tables, rain events, and/or the damming of local waterways. Just as with fire, the

A seasonal, emergent wetland sits under an open canopy in Florida. The local vegetation is well suited for such waters, which are present after rains but dry up each year.

different types of naturally occurring floods can have diverse effects on local habitats. The velocity of water entering the habitat affects sediment loads and scouring, and whether soils and rocks will be deposited or exposed. High-velocity floods typically happen near large watercourses or in mountainous riparian habitats. Slow-velocity floods can occur near main waterways in flat terrain, in localized concave reliefs, and in areas with high water tables.

In addition to velocity, the duration of a flood can drastically alter the effects on local communities. Short-term flooding or seasonal flooding is important for many animals, like amphibians and various arthropods. A myriad of habitats have seasonal floods, which can create vernal pools that many types of wildlife need; but overall, the plant community structure remains intact in short-term flooding. Conversely, long-term flooding caused by localized impoundments and changes in hydrology can cause vegetation die-offs and provide new habitat for obligate wetland plants. Long-term floods can occur after forces alter drainage patterns like sandbar deposits, landslides, and damming of local waterways by debris or beavers.

Ecosystems with large waterways and local depressions, especially in areas with flatter terrain, often include floodplains and seasonal wetlands. These areas can host plants that can tolerate periods of inundation and drought. Plants that tolerate short-term flooding and dry periods are known as facultative wetland plants and are great for rain gardens. In the United States, the best place to learn more about a plant's ability to grow in wetlands is on the plants.usda.gov website, under the "wetland" tab on the profile for the species.

Most ecoregions contain habitats that are dependent on occasional flooding, while other habitats can be drastically changed. Flooding an area can have dramatic effects on plant and animal communities. Floods from surface water can transport sediment,

A small mountain stream, with clear signs of velocity changes throughout the season, flows through a forest. Stream velocity changes throughout the year and over time, which cleans out detritus, silt, and vegetation.

Tall trees emerge from the standing water of a swamp. Seasonal changes in water level can expose soils or further cover the trunks, which these plants are evolved to tolerate.

organic materials, and nutrients, and facilitate dispersal. Severe floods can scour regions, removing nutrient-rich soils and organic matter. The disturbance from a flood can create areas for new colonization and displace or kill flood-intolerant species. Soils that are exposed to recurring flooding and inundation change chemically as oxygen is generally depleted from them quickly. Plants that can live in these soils have evolved ways to handle anoxic conditions (suffocation) around their roots.

Throughout most of North America, North American Beavers (*Castor canadensis*) historically influenced localized flooding. The animals would dam up small to medium-size streams with logs, which would allow areas upstream to spill over their banks and flood areas. In some cases, generation after generation of beavers maintained the dams, creating small lakes. In areas with higher generational turnover, floods would

A large wetland influenced by North American Beavers (*Castor canadensis*) creating dams. Their hut is located in the center of the shallow waters. In the background, a dense stand of dead upland trees is visible; these trees cannot survive the inundation, which creates new habitat for nesting birds, insects, and full-sun plants.

often kill off many trees that cannot grow with submerged roots, while flood-tolerant herbs, shrubs, and wetland trees were able to establish. All of these wetlands were also important firebreaks, amphibian and fish breeding grounds, and drivers of landscape diversity. Flooded areas from beaver dams are different from floods from rain events in that sediment deposits are typically much less significant.

Floodplains

Riparian areas with low-grade slopes and meandering streams often have floodplains along their banks. These areas fill with water seasonally or during large precipitation events, depending on the region. Floodwaters can deposit soils, wash away detritus, and deposit new organic matter. Low-lying areas in the floodplains hold water after the floods recede, providing important habitat for amphibians, insects, and plants. Urban and suburban areas often channelize streams and install levees to prevent floods, destroying these important habitats.

Along some rivers and tributaries, urban planners have listened to ecologists and started rebuilding floodplains to both reduce flood damage and provide essential habitats. For the typical landowner, however, floodplains cannot be restored. Although re-creating floodplain habitats without the presence of streams would mean the lack of some key characteristics, artificially flooded areas support insects, mollusks, amphibians, and native plants as well as a variety of additional wildlife species.

A stream with emergent wetland fringe and sloped banks. Seasonal flooding increases water flow to flood the higher banks and parts of the forest, known as floodplains.

An urban stormwater channel after a brief rain in Corpus Christi, Texas. This classic design removes water as fast as possible and does not consider ecological processes nor reduce potential flooding downstream.

— Annual Precipitation Patterns

Wet Years

In drier ecoregions and upland habitats, years with above-normal rainfall and events can drastically affect plant communities and the establishment of young perennial plants. Research projects in North America have mostly focused on the arid Southwest for long-term plant community changes with respect to rainfall. However, anecdotal evidence and overall gardening practices illustrate that perennial plants starting from seed benefit from above-average precipitation and rain events. Conversely, extreme increases in rain can lead to plants drowning and not establishing, which is occurring more frequently due to climate change in many areas.

Some of the encouraging research findings show that plant communities in drought-stricken areas can rebound quickly after a wet year. Perennial plants that need some water to sprout and establish will dry out and fail to persist in drought years. In wet years, seedlings of perennial plants are able to grow deep enough roots to establish, allowing them to survive future drought years. Gardeners and conservation groups mimic wet years by watering newly planted trees, shrubs, and herbs until they have grown sufficient root biomass and then irrigating as needed.

In wild areas, the plant communities and habitat structure also play a role in the establishment of young plants during wet years. Annual plants help shade exposed soils, which increases water retention by the soil. Arguably, one of the more famous North American responses by wild plants to wet years are the super blooms of California. Not only are these blooming events truly stunning to see; ecologically, they are extremely important. Most of the flowers in these super blooms are annuals, which help protect emerging perennials by blocking direct sunlight and decreasing direct wind speeds, which increases overall humidity and prevents desiccation, or the drying out, of sprouts while also keeping moisture in the soil. Rocks, logs, slopes, perennial plants, and small catchments also affect the abiotic factors and can help perennial plants establish.

As perennial plants mature, they begin to keep the soil below their branches cool and help reduce wind speeds, which also increases available moisture. Increased soil

The seasonal end of a local major blooming event. Massive blooming events provide copious amounts of food for pollinators, caterpillars, and herbivores.

moisture under plants is most prominently observed in areas where fog is common and tree canopies create fog drip. This phenomenon is discussed further later in this chapter, in the section "Plants as Ecosystem Engineers." The microclimate in and around mature plants creates better conditions for other plants to establish. This change in microhabitat and the ability to support other plants are characteristics of what are known as *nursery plants*. Similarly, fallen logs are often referred to as *nursery logs* because they help create localized conditions that support the growth of new plants.

Tending to our gardens and removing unwanted vegetation help prevent weeds from becoming nursery plants for successional species. In some cases, growing certain species to help facilitate the growth of seedlings can be more successful than seeding target species by themselves. In conservation work, cover-crop seeds are mixed with native seed to improve the establishment of native vegetation. In our gardens, when native-seed mixes are used for larger areas, it is beneficial to have a high abundance of native annuals in the mix or to use a non-invasive annual like wheatgrass. As the annuals grow, they will create better growing conditions for the perennial plants, mimicking the natural processes like the super blooms. In larger spaces, it is also helpful to place large branches, mulch, and rocks to help collect wind-dispersed seeds and create local nurseries and different microhabitats.

Drought Years

Historically, droughts have not been uncommon in any ecoregion. Droughts can be discussed as short-term or long-term, and both time frames have scalable intensities. In short-term droughts, precipitation events are interrupted with longer than normal dry periods for the region. A long-term drought focuses on seasons and years when

Shortgrass prairie in the middle of summer and a decades-long drought. Shrubs and perennials, successfully established during wet years, are able to survive these conditions, but seedlings will not survive.

the seasonal or annual precipitation is below average. Drought severity depends on the length of the drought and the frequency of precipitation. For example, an area can receive half of the normal precipitation in a year. However, if the area is still receiving precipitation events frequently, many of the plants and animals will pull through. In contrast, if an area receives near normal amounts of rain over half of the rainy season and then no rain the rest of the year, many plants and animals will not be able to survive.

Ecologically, droughts can lead to animal migrations, plant mortality, and habitat turnover. Climate change is leading to more frequent droughts, in both short-term and long-term patterns. Many plants respond to short-term droughts by growing deeper roots and are easy enough to allow in gardens by withholding supplemental watering. Long-term droughts, however, can be devastating. With the amount of current habitat loss and population declines, there is no reason to allow long-term droughts to affect areas where we can supplement water. This does not mean that gardeners should create habitats with high water demand. It does mean that watering stations should be filled and supplemental waterings should happen to prevent plant and wildlife loss.

Long-lasting droughts dry out perennial wetlands, leading to local die-offs of animals and plants. When rains return, these habitats form again, and populations can re-establish. This process regularly removes diseases and parasites as well. Without movement of populations, it is important to monitor their health and take action when problems like diseases or heavy parasite loads occur.

Habitats and Microclimates

— Abiotic Factors

Within ecosystems, *abiotic* refers to the physical characteristics of an area, including precipitation, temperature, light, water availability, soil chemistry, soil structure, and physical structures. Even though these features are not considered biological, they can be drastically influenced by living organisms. Precipitation, humidity, soil chemistry, physical structures, light, and even temperature are heavily affected by vegetation communities. Animals can also significantly affect soil chemistry, water availability, and the physical structure of an environment. For example, animal defecation, urination, rooting, and burrowing affect soil chemistry and can affect the water retention capability of the soils. Similarly, large animals can compact soils along trails and create deep hoofprints along wetlands. Understanding the influence species can have on the abiotic factors of an area, especially microclimates, allows us to better plan restoration projects.

Microclimate can mean anything from a very small area, like the north side of a fallen log, to fairly large areas, like the north side of a mountain. In general, it is used to separate a smaller area from a larger region that has different climate than the overall space being discussed. When viewing a landscape or habitat, understanding that some spaces have more suitable conditions for specific plants and animals is critical to re-creating key habitat resources. Local depressions in meadows collect water, promoting some plants over others. Fallen logs exposed to the sun provide dry nesting sites for many insects, while fallen logs in shady areas create spaces with more moisture.

A rather large percentage of plants and animals have niche requirements that can be difficult to maintain on our own. For example, Metallic Green Sweat Bees

Stones, crevices, light exposure, water availability, and soil types affect microhabitats and determine which plants can survive. This rock outcropping shows a variety of microhabitats mostly affected by abiotic factors.

(*Augochlora pura*) need damp, decaying wood to overwinter in, cavities to nest in, and floral resources to provide nectar and pollen. Although it is a bit absurd to think anyone would attempt to provide resources in a habitat as an isolated project, let's consider each resource individually for argument's sake. If we were to take a barren plot and try to create habitat for these bees, planting an area with the appropriate floral resources and irrigation would be easy enough by selecting appropriate plant species and allowing enough space to provide forage. Providing cavities for nesting would require a little more attention—for example, to ensure that logs are dry enough but not too hot and that cavities are the right size. In an isolated situation, the nesting area would need a shelter and shading setup. Creating a damp, decaying log with just the right amount of moisture would be rather difficult and require some

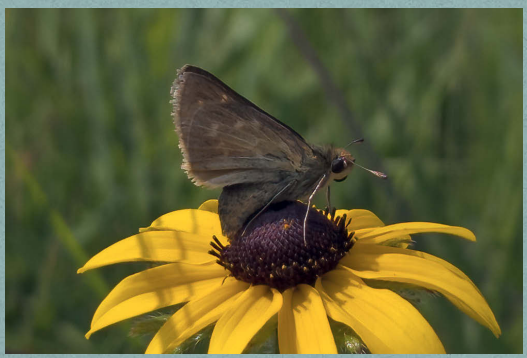
Two overwintering adult Pure Green Sweat Bees (*Augochlora pura*) are exposed in a crushed, late-stage decaying log. Wood in this state retains moisture and stays warmer than nearby areas due to chemical reactions.

Springtail (class Collembola) colony sitting on the surface of stagnant water in a hoofprint. This microclimate is important for these arthropods, which are prey for many other species.

sort of contraption to make sure water was being added at the correct rate, and some sort of shelter would be needed to keep the log out of the sun. Again, it would be ridiculous to make a species-conservation plan in this way because a well-designed habitat creates the necessary microclimates.

Designing habitats still involves ensuring that forage plants are available and providing nesting resources and overwintering places. However, instead of building structures and mechanisms to create suitable climates in the barren plots, microhabitats present in the landscape and included in the restoration plan can be utilized. Newly planted trees and existing buildings can keep nesting areas at the appropriate temperature and adequate moisture availability with some supplemental watering. Overwintering logs might be placed in the deep shade of newly planted trees, shrubs, and vines and surrounded with modified soils that retain more moisture.

THE NEEDS OF THE DAKOTA SKIPPER



A female Dakota Skipper (*Hesperia dacotae*) resting on a Black-eyed Susan (*Rudbeckia hirta*) flower in a lowland habitat.

In the remnant prairies of central Canada, Minnesota, and North and South Dakota, a small, threatened butterfly, the Dakota Skipper (*Hesperia dacotae*) can be found. Its habitat includes two distinct areas—hillslopes with native bunchgrasses, floral resources, sandy soils, and high humidity, and lowland areas that do not flood, with similar conditions to the hillslopes. Caterpillars of this species build a nest at the base of grasses and spend more than 11 months just underground. Adult Dakota Skippers fly for about three weeks between June and July and can be found in the larval habitats.

As ecologists learn more about this butterfly, data show that this species avoids grasslands with invading grasses, thick vegetation, shrublands, and barren slopes. The loss of habitat to agriculture, the increase in invasive species, and native shrub encroachment are due to historical land-management practices being replaced with

— Full Sun

A wide variety of plant communities grow in full sun, which is botanically defined as six or more hours of direct sunlight daily during the growing season. This includes tall plants growing in grasslands, open meadows, marshes, and shrublands, as well as the trees that create forest canopies. Unlike plants, most animals cannot endure exposure to the sun constantly throughout the day. Yet, although a plant might be considered tolerant of full sun, many species do poorly with constant exposure, especially in the hottest parts of the year. Herbaceous meadow plants, for example, need full sun, but they also do best in dense plantings that allow neighboring plants to provide windbreaks and shade during the late afternoon. Plants also have to adapt to seasonal temperatures, water loss, and heat. Rapid changes in sun exposure can kill plants. In wild settings, tree falls leave unadapted plants exposed, which can

European practices (row-crop agriculture, land privatization and removal of native megafauna, and fire suppression). For a habitat to support the Dakota Skippers, it must have host plants, floral resources, and a very specific range of abiotic factors. Although most species in urban environments tolerate broader ranges of abiotic factors for habitats, the Dakota Skipper illustrates how important small differences in an area can affect a species' survival.

Tallgrass prairie habitat in the northern extent of the Badlands, in North Dakota. Large swaths of prairies are punctuated by shrubs, forested areas, and steep, unvegetated slopes.

Many forest trees like these *Populus* species and evergreens in the background are full-sun plants that provide shade. Similarly, plants growing in open grasslands, prairies, and many riparian areas do well in full sun, while also providing shade for the soil and ground-level vegetation.

lead to leaf wilt, scorched leaves, or localized burns, and can even kill the unadapted plants. Even large branches of trees breaking can leave parts of the tree accustomed to shade at risk of being burned and susceptible to infections, a common issue with fruit trees.

In landscape designs, many plans include drastically spaced-out plants with exposed soils or mulch between plants. Sometimes this is to provide enough room for mature plants to fill in, while at other times it is intentional to create a "crisp" appearance. Such designs often lead to stressed and dying plants in the midsummer or autumn heat and require more frequent watering. Adding shade cloths can decrease stress and heat while plants establish and adapt to an area, but a more natural approach is to fill those areas with other plants, including annuals, biennials, smaller

Black-eyed Susans (genus *Rudbeckia*) grow alongside grasses and other full-sun plants in an area with more than six hours of sun each day during the growing season.

Planter bed with unnaturally isolated plants and mulch. The mulch protects the soil a bit and prevents water loss, but dense planting of annuals to cover the soils provides better, more natural microhabitats for the plants to establish in.

perennials, trailing plants, and bunchgrasses. This more natural design also benefits wildlife and improves the overall habitat.

— Shade

Quite often, people think about lighting in the environment as sun or shade, which conveys the idea that there are only two types of lighting. However, shade is simply an umbrella term that covers many different levels of light in an area. The four most common categories used in horticulture are: part shade, dappled light, full shade, and deep shade. *Part shade* describes areas that receive four to six hours of direct sunlight. In nature, part shade is found near cliff faces and under isolated, tall trees with dense canopies. Due to the potential for direct sun, part shade can be further clarified by specifying the amounts of morning sun and afternoon sun due to the climatic differences sunlight has on an area at these times. *Dappled light* is when small patches of sunlight reach the ground. This is typical under some species of trees, under latticework, and in forested areas with spaced-out trees or loose canopies. Dappled light can also occur in areas under tall herbaceous plant communities in drier areas where exposed soils are present between bunchgrasses and low-growing shrubs. *Full shade* describes areas that do not receive much, if any direct sunlight, but are still bright enough for many shade-tolerant species to thrive. Naturally full shade occurs in open forests with dense canopies, under trees with large canopies, and on the north faces of rock shelves, canyons, and gullies. *Deep shade* describes areas that are too dark for most shade-tolerant plants to thrive. In wild landscapes,

A cave opening in the Spring Mountains, in Nevada. Light levels in the foreground are deep shade, but the area receives enough refracted light for some mosses and herbaceous plants to grow. Trees in the background receive full sun along their canopies and provide dappled shade to lower vegetation.

Palm trees growing in part sun under open pine canopies in Florida. Healthy management of these forests provides wide openings that allow sunlight to reach the forest understory.

deep shade occurs under dense shrubs, thick forests, below rock overhangs, and in cave entrances.

On a large landscape scale, shade types are important in descriptions of some habitats and areas like closed-canopy forests and the north faces of mountains. However, shade is typically discussed on a small scale specific to an area covered by a single plant, since plants depend on light to photosynthesize. Although all of the lighting types exist in urban and rural areas, the number of areas with deep shade has drastically increased because many buildings create it on their north side.

— Water

In every ecoregion in North America that has plants, water availability and abundance are major contributors to habitat, animal presence, and plant-community structure. Water availability includes frequency of rain, annual and seasonal precipitation, humidity, groundwater depth, surface water, and soil moisture.

Precipitation

One of the key differences between the Level I ecoregions of North America is the amount of precipitation each receives annually and seasonally. Differences in seasonal precipitation influence plant community structures and microhabitats, which are key to many animal life cycles. For example, in the Marine West Coast Forests ecoregion, chilly winter rains and snow raise groundwater levels, creating ephemeral springtime wetlands that are breeding grounds for cold-tolerant, cold-blooded insects and amphibians. Compare this to the North American Deserts and the Great Plains ecoregions, where summer rains create warmer ephemeral pools during hotter weather, when many cold-blooded animals are more active.

Large storm cloud near sunset that released over an inch of rain in less than three hours. Most soils cannot absorb water at this rate, which leads to localized scouring and flooding.

In the high desert and sky islands of New Mexico, rainstorms are often isolated and provide precipitation for localized areas. These storms are more common than rain events occurring across most of the landscape.

To be clear, there are numerous compounding factors that influence the amount of precipitation, seasonal differences, and water retention in an ecoregion. However, for the purposes of this section, precipitation will be discussed on a local scale. Seasonal precipitation patterns drive the life cycles of many organisms, including plants, fungi, and animals. Some ecoregions receive the majority of their precipitation in certain parts of the year. In the deserts, this is often called the "monsoon season," when the Mediterranean California climate experiences rain in the winter and spring. For ecoregions with wet and dry seasons, the ecosystems are adapted to annual droughts. To contrast with this, some ecoregions experience precipitation events throughout the year, like in the Upper Midwest and the Northeast. Ecosystems that receive rain and snow throughout the year have more water available to plants and animals that are less adapted for long, dry periods. Even though areas are still receiving precipitation, climate change is affecting precipitation patterns. Rainstorms are becoming less frequent in many areas, creating longer periods of drought followed by stronger inundations. This is harmful to habitats because organisms are stressed and killed in these extended weeks of drought, and then too much water follows. More intense rain events lead to longer flooding periods, different intensities of floods, and erosion, as well as increased stress and mortality pressures on organisms.

Understanding the historical rain patterns of an area is important because this knowledge does several things: it helps tell us when to water plants; it is a guide for

when to provide ample clean water; and it allows us to notice the problems climate change is causing. As droughts become more frequent, providing plants with supplemental water can help an entire habitat survive. Similarly, garden designs should include proper drainage for times when precipitation is excessive.

Aquatic Habitats

When water in natural landscapes is discussed, many people immediately think of picturesque rushing rivers, gorgeous waterfalls, large, still ponds, and lakes. Even in major city installations, waterfalls, fountains, and ponds are the chosen aquatic feature type. However, water resources in the wild exist in a vast array, including the picturesque resources mentioned above, but also as muddy puddles, rocky-bottomed rain catchments, and heavily vegetated emergent wetlands that might be seasonally available or filled with water year-round.

Slot canyons, formed when seasonal rains carve out the walls and floor, are common in parts of the arid Southwest.

Picturesque aquatic habitat with wetland vegetation growing along the streambed.

Ecologists, biologists, and land managers have devised a variety of ways to describe water resources and the habitats they create. For the purposes of this book, standing water resources will be described with less technical terms. Most people can understand "muddy puddle," "meandering creek," and "vegetated pond," while technical terms like *palustrine* and *unconsolidated bottom* generally need further clarification. Just as for terrestrial environments, there are many ways aquatic habitats can be categorized. Aquatic habitats are affected by lighting, with shaded areas heating up less quickly than areas in full sun and the two supporting different vegetation and biotic communities. Similarly, the depth of water, its movement, the substrate, soils, and other elements all affect which species can live in these bodies of water. The depth of water bodies can affect temperature, provide refuge from terrestrial predators, and correlate to the persistence of the aquatic habitat in the landscape. Movement of water affects oxygen levels; fast-moving streams have more oxygen than slow-moving streams of the same temperature.

Depending on the habitat and ecoregion, standing-water habitats, like pools and emergent wetlands, can be common year-round or only during the rainy season. For all regions, these water resources are used by a variety of species. Most species rely on the habitat for drinking, some rely on it for hunting, and others need these habitats to complete their life cycles. In most cases, larger aquatic habitats (those that can persist for weeks to months after rains) are key resources for the life cycles of some native arthropods (including insects), fish, and amphibians. Animal life cycles that are dependent on aquatic habitats can be separated by the presence or absence of fish. Because most fish are predators, fishless habitats are vital for the larvae of amphibians, many dragonflies, and a variety of other insects. For example, mosquitofish (genus *Gambusia*) and their relatives are especially damaging to amphibian populations because they eat larval amphibians and their eggs, or simply peck at their tails,

limbs, and gills, leading to death. Unfortunately, people have released mosquitofish in many wild aquatic areas to help control mosquitoes, with little success. (See the chapter 3 section "Mosquitoes" for other control options.)

Due to the wide range of natural aquatic habitats, for the purposes of this book, discussions will focus on habitats that can easily be reconstructed in small gardens. These habitats include puddles, fountains, seasonal ponds, vegetated wetlands, and even small, seasonal streams.

Roadside ditch culvert with abundant mosquitofish (genus *Gambusia*) and crayfish (superfamilies Astacoidea and Parastacoidea) in their native range. Both types of animals are widely invasive in other areas of the continent and world.

An American Toad (*Anaxyrus americanus*) sits in a small, rocky depression, soaking up water from sprinklers, in Westchester County, New York. Intentionally providing areas that collect water for short periods of time greatly benefits garden wildlife.

Puddles and small water catchments are found in all ecoregions after rains. They usually persist for a few hours to a few days after storms, quickly draining or drying up. Some form in soil depressions, others on rocks and even on plants and fallen leaves. These small, fresh bodies of water can provide drinking water for animals, as well as areas for bathing and soaking. Wet soils in and around puddles are used by a few bird species, a variety of wasps, and some bees to build their nests. In developed areas, many of the soils where puddles form are filled with pollutants from roads, including salts, which makes the water less suitable for drinking and the soils less suitable for nesting. Irrigated areas, however, provide these resources more regularly than natural cycles and can improve water access for animals and provide nesting resources for longer periods. In arid regions, urban development has helped swallows become more abundant due to the increase in mud and puddle availability, while bridges and building faces have provided new nesting spaces.

Longer-lived temporary bodies of water provide many of the same functions as puddles, but also persist long enough for some animals to carry out a stage of their life cycle or complete it. In drier regions, these areas are often called *playas* or *dry lakes*, while people in wetter regions often refer to them as *ephemeral pools* or *vernal pools*. Temporary bodies of water rarely support fish and can be vegetated or barren. While water is present, these areas support the complete life cycles of aquatic invertebrates like fairy shrimp, water fleas (genus *Daphnia*), and seed shrimps (class Ostracoda), as well as life stages of various amphibians and insects. As the watery habitats dry up, chemical changes in the water signal to wildlife to either emerge or complete their reproduction.

Longer larval periods help some salamanders, frogs, and toads grow larger and make them better suited for starting terrestrial life. Conversely, some species, like

Swallow (family Hirundinidae) nests along an overpass. Local mud resources and the sheer face of the infrastructure create prime nesting locations, and insect abundance provides great foraging.

Bladder Snails (*Physella acuta*) in a roadside trough, in Texas. They are regularly found in perennial and almost-perennial water bodies.

Couch's Spadefoot Toad (*Scaphiopus couchii*), have been found to do better when ponds dry up in a few months and have lower survival when ponds persist for longer. For some species, this is potentially due to differences in diet and prey. For amphibian breeding habitats re-created in gardens, it is critical to make sure the habitats suit the local species. Prior to installing any type of habitat project, research the target animals and their life cycles so that habitat characteristics, like the duration of water presence, mimic natural processes and vegetation.

Vegetation often grows in and around seasonally submerged habitats that can tolerate both dry and wet conditions. However, in arid regions, many playas (salt pans) do not support vegetation due to salt buildup in the soils and/or soils deprived of oxygen because of the sun-heated water. In wetter ecoregions, vernal pools can form in almost every type of habitat, including shaded forest floors, dense shrublands, and sun-exposed meadows. Each habitat can support different wildlife and plants within the vernal pools. In forested habitats, animals that live in the pools typically feed on leaf litter or plants already growing around the area. Algae is not a common food resource in these shaded habitats because most algae species need more light to flourish. The lack of sunlight also helps the water stay cool. Predatory organisms also live in the shaded pools, preying on other inhabitants. Shrublands and meadows typically have more light exposure, so more types of algae can grow. Waters in these sun-exposed pools can have drastic daily changes in temperature, which affects oxygen availability and metabolic processes. Animals and plants living in these pools have evolved different ways to handle these changes, with some species having seasonal restrictions for activity within the habitat, while others can breathe air when

An abandoned golf course in Texas supports deep wetlands with emergent wetlands along the shore. Tree cover on the south side provides habitat for rushes and broadleaf plants, while full-sun areas are dominated by cattails (genus *Typha*) and reeds.

necessary. Diets of animals in these pools may include floating algae, plant materials, and/or other animals living in the water. In gardens, re-creating these habitats should focus on the target wildlife, which typically benefit from partial sun exposure and water columns that are 2 to 3 feet (0.6–0.9 m) deep.

Perennial Ponds

Small, permanent water bodies are more common in ecoregions with year-round rain, but can also be found in drier environments. Perennial ponds are generally home to various aquatic snails, amphibian larvae (especially species with longer development periods like the American Bullfrog (*Lithobates catesbeianus*), certain dragonfly larvae, and a variety of other invertebrates. Organisms that use longer-lived seasonal pools often utilize perennial wetlands as well. Many ecoregions also have native aquatic vegetation, including complex green algae, horsetails (genus *Equisetum*), and flowering plants. Some examples are muskgrass (genus *Chara*), scouring rush (genus *Equisetum*), American Lotus (*Nelumbo lutea*), and American White Waterlily (*Nymphaea odorata*), all of which do well in deeper ponds. Emergent and bordering vegetation that prefers shallow waters, like rushes (genus *Juncus*), cattails (genus *Typha*), and Aquatic Milkweed (*Asclepias perennis*), generally do not do well with long periods of dry conditions but survive short seasons. Wetland plants also help shade the water, create microhabitats within the water body, and provide food for various animals.

Around human developments, small perennial wetlands are often filled in unless protected by law. This is because most people incorrectly equate standing water with stagnant mosquito breeding grounds. In reality, mosquitoes do best in degraded

Muskgrass (genus *Chara*) is a green alga that looks like a plant. These algae are common in freshwater, perennial, slow-moving bodies of water, including cattle troughs.

wetlands, but their larvae are mostly consumed in healthy wetland ecosystems. Water bodies that remain in developed areas are often polluted by runoff from roads and chemically treated lawns, as well as windblown trash. Pollution also occurs in agricultural areas from both agrichemicals and animal waste. The majority of invertebrates and amphibians that rely on these habitats are sensitive to pollution, nutrient levels, and overall water quality. In fact, scientists have created the Stream Health Assessment tool to evaluate the health of streams based on the presence or absence of specific aquatic species; state-specific tools are usually available through extension offices and state agencies. Stream Health Assessments rely on identifying aquatic insects and amphibians to calculate scores that correlate to the health of the water body. Many of the insect and amphibian larvae found in healthy streams can also be found in healthy perennial ponds.

Re-creating perennial pools in the garden is fairly simple with a little patience. There are premade shapes available, and fabric pond liners that hold water in free-form pits. Placing the pond in an area that receives enough light for the target habitat

A skimmer dragonfly (family Libellulidae) adult with prey. Dragonflies are important generalist predators that need water bodies to carry out their life cycle.

is key; for example, six hours of daily sunshine is necessary for irises (genus *Iris*), cattails (genus *Typha*), and waterlilies (family Nymphaeaceae). Two to four hours of sunlight a day helps keep water temperatures down and reduces algae growth. Once a pond liner is installed, adding stones, soils, sand, and a pump to aerate the water will start the habitat. Animals may arrive very quickly, with dragonflies and damselflies (order Odonata) usually the first insects to show up. After the water cycles for a few days, plants can be added. For more details on pond habitat designs, see the chapter 2 section "Water Resources in the Garden."

— Soils

Often overlooked when considering natural landscapes is the diversity of soils that exist in an area, because many habitats have covered soils and soils can be characterized in different ways. Depending on the purpose of the classification, soils can be grouped by temperature range, water retention, texture, pH, and nutrient availability. Most of these classifications, however, are not independent of one another. For example, ecoregions are often thought about in terms of the amount of precipitation they receive; however, soils are a major contributor to the water availability for plants. Water availability is influenced by precipitation, but in the end, it is determined by soil structure, permeability, texture, depth, organic content, pH, and nutrient levels. Vegetation and soil biota also depend on soil texture and water availability, which are key factors driving nutrient cycles and local soil temperatures via sun exposure. Soil

A deep cut from erosion exposes layers in soils and root depth. Very few habitats have deep, nutrient-rich soils (top dark soil layer above), and many have bedrock that plants must contend with, which is not present here.

pH affects nutrient availability for plants and animals and the nutrient cycle. In other words, there are specific variables in soils, but those variables are not necessarily independent. Even with the nebulous entanglement of soil characters, each aspect can still be understood as it applies to habitat.

Temperatures of soils are affected by texture, moisture, slope, depth, and exposure to the sun. Thermal extremes of soils are critical to the survival of many soil-dependent organisms. For example, bees, lizards, and turtles select nesting sites based on soil texture, aspect, and moisture content, which vary by species. Species that overwinter underground will not survive if temperatures get too low or stay too warm. Some plants even require soil temperatures to drop below specific levels before they will grow again (aka chill hours). In the summer, soil temperatures are important for burrows, nest sites, and other shelters, and poor placement can lead to the complete failure of nests, affect the sex of young (as in some turtles), and create areas where it is too hot for animals to shelter and plants to grow.

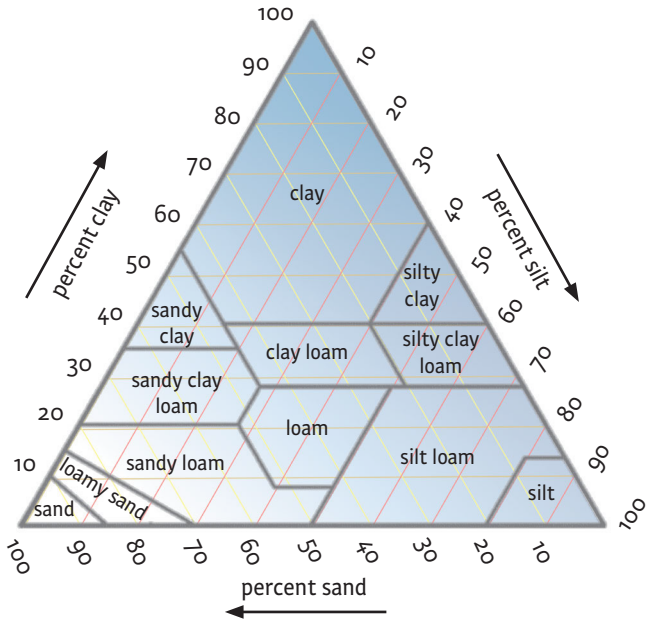
Viewing the landscape on a broad scale, soil temperatures can be assumed based on the slope and cardinal direction (aspect) the soils face. On steep mountains and rolling hills in the Northern Hemisphere, north-facing soils have the lowest temperatures in the winter and the summer due to the lack of direct sun throughout the day. Northern faces also tend to have the most water availability compared to the other aspects. East-facing soils have slightly warmer ranges for the area as they are mostly warmed by the early-morning sun. South- and west-facing slopes have

A turtle excavating its nest in soft, organic-rich soil. Turtles will search far from their regular watery habitat to find the right microhabitat for their eggs.

the highest ranges as they are the most exposed during the hottest parts of the day. Water availability is also assumed to be lower on the south and west aspects, as it will evaporate more readily with the increased heat.

On a small scale, slope and aspect are still important, but soil temperatures are also affected by exposure. Soils shaded by tall trees, dense shrubs, downed logs, rocks, erosional features, or other structures can have cooler microclimates compared to soils exposed to the sun. Habitats are also affected by flowing water (both rain and streams), as well as wind; both sort soil material and affect soil types. Biotic factors also diversify local soils. Burrowing animals excavate and deposit nutrient-poor soils, while toppled trees lift nutrient-rich soils into vertical shelves while also exposing nutrient-poor soils underneath. Plants and fungi can affect the pH and nutrients available, while insects and animal tunnels can aerate soils. Both animals and plants are able to utilize some of these soils while avoiding others for their life cycles.

The texture of soil affects topography and water availability, and it is important for many animals that burrow and shelter in soils because texture affects the soil's stability and thermal insulation. Soil texture is most often classified using a three-axis key, known as a ternary diagram. The three axes are the percentage of sand, silt, and clay that make up soil. Those components are laid out on axes that make up the outside of the diagram. Not mentioned in this diagram is the incorporation of larger stones, such as gravel, organic material, pH, or compaction, which can affect soil nutrients and water-holding potential. By laying out the percentages of sand, silt, and clay, we



Ternary diagram that maps soil components used to classify soil texture. Percentages of sand, silt, and clay are measured by shaking a soil sample in a straight-walled container and marking lines where materials settle at one minute, one hour, and one day.

can classify soils in a meaningful way that permits concise discussions. Having clear descriptions of soil textures allows us to convey information and to quantify soils in a way that is useful for identifying plant and animal preferences. These preferences are important in conservation because they assist with rebuilding soils to support target organisms. Ternary-diagram-based classifications can also be further described with other characteristics, including nutrients, pH, compaction, organic material, and moisture content. How to measure sand, silt, and clay content is explained in the chapter 2 section "Creating Soil Profiles for Plants and Animals."

Another aspect to consider for soil diversity is the layering of soils. Depending on the ecoregion and habitat, soils can have a variety of layers near the surface or just one. In communities with rich vegetation, there tends to be an organic layer sitting on top of nutrient-rich topsoils. However, areas like alluvial fans (gravel and sand deposits from rushing water), sand dunes, and exposed bedrock can have pockets of organic material and topsoil, but there is not a consistent layer. For habitats that have thick topsoils, a subsoil that tends to be lighter in color forms. Subsoils have lower humus content, are comparatively more rigid and compact than the topsoil, and have less organic content. Conversely, subsoils are mineral-rich, because water-dissolved minerals and salts are able to concentrate in this layer. In wet habitats, these soils can become oxygen-deficient or anoxic (oxygenless), which is one of the stressors wetland plants must contend with.

Uprooted trees often expose soil layers and create topographic changes that are not considered in the ternary diagram. Soil nutrients, slope, and aspect affect the microhabitats that will form. Re-creating these microhabitats is difficult in gardens and restoration projects. However, exposed vertical soils can be provided in well-designed rock walls. See chapter 2: Burrows, Caves, Crevices, and Rocky Shelters.

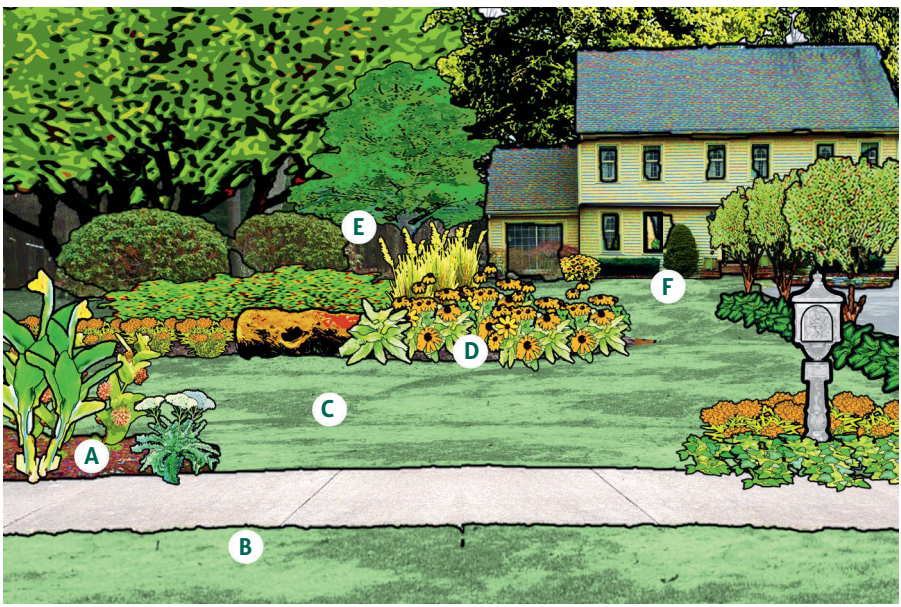
A fallow urban lot colonized by prairie dogs (genus *Cynomys*) in Westminster, Colorado. Previous soil compaction and construction work on this site makes it unsuitable for many native plants.

Within each ecoregion, there will be bountiful combinations of soil texture, depth, layers, temperatures, and water availability. Each combination permits or excludes some plant species while also being selected or avoided by wildlife—overall, driving local habitats and microhabitats. These different combinations can become hard to calculate as we consider larger habitats. In conservation, however, this complexity is often overlooked. For some restoration projects, environmental engineers try to replicate some

of the soil diversity, especially with wetland and riparian habitats, because soil-erosion prevention and plant habitats require specific soil properties. However, many upland projects fail to incorporate soil diversity. Most often, areas are smoothed over and seed mixes are spread with the assumption that soil diversity will form on its own. Although some of the diversity will return in these projects, most of the soil diversity that existed in the natural environment will take decades to form again, and that is only if the restoration is allowed to undergo natural habitat successions.

In urban and suburban areas, soils are generally modified with nutrient-poor, dense earthen materials that are better for building stability. This is even more prevalent in newer housing developments. Agricultural practices and urban development homogenize soils, disturb topsoils, grade steep slopes, fill in caverns, and remove most local soil diversity. Subsequently, some species of wildlife that have specific soil needs are pushed out. Some examples include halophile plants that grow in salt-rich depressions, sand-dune-dwelling bees that nest in the sand, and cliff-nesting animals,

Soils around houses will likely vary based on disturbances and vegetation. Testing these different soils can help determine where soil amendments may help nesting animals. Similarly, adding specific soils to these spaces provides nesting options for wildlife. In the diagram are some great locations to test and consider amending. (A) Exposed garden-bed soils. (B) Soils near cement work because sand is often used as a base. (C) Mowed vegetation areas. (D) Shaded soils in garden beds. (E) Soils under large shrubs and trees. (F) Soils near foundations and around HVAC units.



like swallows and bees. Although rebuilding soil diversity in its entirety is nearly impossible, it is fairly easy to re-create topographic and texture diversity. For example, incorporating deep, sandy areas around rockscapes and paths, between plants, as well as around houses and fence lines diversifies soils with no major change to the appearance of the landscape. Further strategies and projects for soil diversification are presented in the chapter 2 section "Creating Soil Profiles for Plants and Animals."

— Temperature

There are a few different ways to think about temperature and the environment. Each approach has merit and describes parts of the local environment, but none fully capture the thermal ranges within an area. Average winter lows, for example, drive the USDA gardening zones, but frost-free periods describe the growing season. Both the USDA gardening zones and growing season length are used to guide crop selection. Considering temperatures on a more localized scale, north slopes are known to be cooler than south slopes, and deep-shaded areas are cooler than adjacent areas exposed to full sun (discussed more thoroughly in the chapter 1 section "Shade"). Similarly, developed areas are known to create heat islands caused by solar heat being stored in building materials and the lack of cooling from vegetation.

Cold and heat extremes in habitats are major factors affecting the ranges of species. However, many microclimates do not have thermal extremes that directly correlate to the local air temperature. For example, deep caves tend to have low variability in their temperatures compared to the surface temps at the entrance. Frost lines (how far down the soil will freeze) depend on a few variables, including the cold air, solar

Cinquefoil (genus *Potentilla*) flowers growing in cold temperatures that are below the extreme for the flowers of most plants. Incorporating early-blooming plants in garden designs helps the pollinators that emerge first in spring.

Winter landscape of a wooded area where many animals overwinter. Within this landscape, leaf piles, burrows, and tree trunks all provide warmer microclimates than the exposed surfaces. Similar resources can be added to garden designs; see chapter 2.

exposure, moisture, and how long the weather stays cold. Similarly, microhabitats reach different high temperatures based on material and solar exposure. Soils and rocks, for example, can regularly be 20°F (11°C) warmer than the air when in full sun.

Although the air-temperature extremes of an area affect wildlife success, the length of time areas stay near those temperatures also has a large impact. This is because areas where wildlife overwinter typically have limited insulation, except for caves. Large logs, soils, even leaf litter will stay above nightly lows if day temperatures and sunlight allow them to warm up. However, if daily highs stay close to nightly lows, then those microhabitats approach the coldest temperatures. A similar pattern exists in the summer and in the heat extremes of microclimates.

In gardens and landscapes, the placement of sheltering resources requires careful attention. Ensuring that the appropriate amount of insulation, solar exposure, and moisture are present will prevent microhabitats from reaching unsurvivable temperatures. Similarly, plants growing in areas of their cold tolerance do better in areas with more solar exposure during the winter than shaded areas. More details on shelter placement are discussed in the following section.

Burrows, Caves, and Crevices

Animals need places to hunker down and escape the elements. Many species take shelter in a wide range of structures in their natural habitat, from downed limbs to picturesque caves. Caves, ledges, and sinkholes are most commonly found in areas with limestone, basalt, and various sedimentary bedrocks. These structures provide necessary protection for a variety of animals, including insects, mammals, reptiles,

A natural rock outcropping with crevices and caves for wildlife to shelter in. Spaces like these are generally removed from urban and suburban environments, but should be considered for installation in gardens to provide suitable shelter.

slugs, and snails. In urban areas, caves are often filled or blocked off, ledges are demolished or covered, and downed limbs and trees are removed. This leaves washouts under cement foundations, basements, and sewers as places for animals to find shelter. Garden designs can include attractive rock shelters, hollow logs, and hidden burrows to provide similar shelter for animals to use.

— Burrows

Some of the most important features wildlife species need are refuges from the heat and cold. This is especially true for animals in hot, dry regions and any other exposed, full-sun habitats during the summer. Similarly, a wide variety of animals overwinter underground to avoid freezing and seek out areas below the frost line of soils. Many natural refuges are built by species such as Coyotes, foxes, jackrabbits, prairie dogs, tortoises, and other large burrowing organisms, most of which are generally extirpated from urban areas. The majority of large, burrowing species have been vilified as pests and extensively slaughtered, some to the brink of extinction. Excavation of burrows and tunnels by these animals also creates loose soil mounds that can be used by animals, like sphinx moths and beetles, that lay eggs, nest, or hibernate in softer soils.

Understandably, large holes appearing unexpectedly in urban environments can be dangerous for people and pets. So instead of trying to keep any large burrowing animals in your garden, we can re-create the needed structures to help our local wildlife. Installing deep, well-insulated burrows helps make better habitat for box turtles, toads, salamanders, crickets, lizards, and countless others. In gardens, burrows can be created with sturdy walls and open floors. Designs are explained in the chapter 2 section “Burrows, Caves, Crevices, and Rocky Shelters.”

Burrowing animals like Black-tailed Prairie Dogs (*Cynomys ludovicianus*) are ecosystem engineers. Their behaviors create necessary resources for many other wildlife. Prairie-dog burrows host hundreds of sheltering species, including Burrowing Owls (*Athene cunicularia*).

A suburban garden with large rocks and an unintentional burrow that became home to toads and lizards after the rodent was removed. Burrow-like structures can be added to garden designs to support wildlife. See chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

— Rocky Ledges, Stones, and Boulders

An incredible array of microhabitats occur in and around geologic formations. These formations include large rock outcroppings, glacial erratics, cobblestones, and exposed bedrock. Although there are many types of stones whose chemistry affects soils, thermal insulation, and even their ability to retain water, many rock types create similar microclimates. This is in part due to local abiotic factors, such as precipitation, winter weather, sun exposure, and wind, which also affect the microhabitats present

A large rock outcropping on Catalina Island, in California. Deep crevices and hollow caves within are important for lizards and endemic island foxes. Smaller-scale shelters can easily be added to landscape designs. For ideas, see chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

in each ecoregion. As rock formations crumbled, cracked, and eroded, organisms continued to evolve to utilize these habitats. Many species of plants, invertebrates, lizards, salamanders, and bats use rock crevices for shelter, while a variety of birds use rock ledges for nest sites. Similarly, an assortment of plants, including some ferns, succulents, and vines, have evolved for living in the specific microhabitats of rock formations.

Rocks are a natural impervious surface, transporting water into nearby soils, crevices, and basins. In the case of exposed bedrock, the rocks prevent the water from seeping into the earth and often create pools, seeps, and springs. Crevices and cracks collect organic matter, sand, and dust, which creates pockets of soils that support plants, function as nesting sites for animals, and facilitate further breakdown of the rocks. Stones that have soils below or around their sides provide a secure structure that some burrowing animals will rely on for structural integrity. Large boulders with soils below them often have mammal burrows beneath, including those of chipmunks, ground squirrels, and rabbits. Some animal species will also tunnel along stone faces extending vertically underground. Ground-nesting insects also utilize these rock/soil interfaces, with smaller stones, depending on the width and depth of their nests and soil composition.

Large omnivores, like raccoons and bears, regularly turn over stones and other objects while hunting. These disturbances create space between the moved items and the soil, sometimes covering plant material as well. Soil invertebrates, like worms, millipedes, and crickets, seek out newly covered vegetation to feed on while also sheltering under newly disturbed objects. Over time, as soils are moved by animals and

A small pocket in basalt provides a pool of water in Idaho. Birds and arthropods hydrate in these open areas.

A large rock outcropping rises above alpine vegetation. The rocks provide shade, soil accumulation, and water runoff for vegetation to establish in.

roots, and as changes in water saturation and temperature expand and shrink soils, the space under the objects can disappear. This phenomenon, often called "settling," creates new microhabitats used by some soil organisms. Without the presence of larger animals to turn over stones and logs, however, the microshelters and feeding areas many animals prefer to use can become very scarce in the landscape. In gardens, objects can be intentionally propped up off the ground to leave crawl spaces or disturbed every few months and placed back in position. For more information, see the "Exploratory Habitat Garden" text box in chapter 2.

Caves, ledges, crumbling rock outcroppings, and sinkholes in urban and suburban areas tend to be covered, filled, or removed. In turn, most of the microhabitats and the species dependent on those areas are extirpated. Some of the animals accustomed to living in and around rocks have adapted to areas around human development. For example, some of the animals that seek shelter in burrows and caverns use washouts under cement foundations, basements, crawl spaces, and even sewers for shelter. Cave-dwelling bats often use city sewers and bridges. Similarly, swallows, bats, and mud-nest-making insects have adapted to use buildings, overpasses, and bridges. On the other hand, most plants and animals that depend on rock-formation microhabitats have not adapted to human development. For many species, there simply are no areas that mimic the key resources they require or soils with the correct pH.

An unidentified vole species (family Cricetidae) peeks out from its home around the rocks, where its matrix of burrows also exists. These features are regularly destroyed and filled in around human developments.

A Cliff Swallow (*Petrochelidon pyrrhonota*) nest tucked into urban infrastructure. These areas are also regularly used by mud daubers (family Sphecidae or Crabronidae) and potter wasps (subfamily Vespidae).

However, with careful planning and attention to detail, many of these microhabitats that were removed from developed areas can be re-created for the more adaptable species. Attractive rockscapes with aboveground and belowground shelters can be designed as focal points or backdrops that support salamanders, lizards, plants, and other wildlife. Vernal pools and seasonal ponds are easy to design and work into garden designs. Planter beds with rock crevice gardens, rock gardens, decorative large rocks, and stone borders can also mimic natural microhabitats for wildlife. For further explanation of designs and resources, see the chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

A toad warms up on a cool day outside the shelter it has found in rocks along a garden bed. Intentionally providing crevices and access to specific soils will greatly improve habitat designs and wildlife health.

CAVES

Caves are important for many animals, including species of bats, birds, fish, and amphibians. In some of Earth's larger, older caves, endemic species live solely in the subterranean ecosystem, while many caves function as sheltering spaces for more mobile organisms. Although talk of caves can elicit thoughts of grandiose underground openings like Carlsbad Caverns, in New Mexico, Mammoth Cave, in Kentucky, or Devil's Den, in Florida, ecologically the term *cave* includes small openings as well as the larger gallery caverns.

Caves are defined ecologically as natural voids or openings with a ceiling, floor, and walls that are often further clarified by a minimum size large enough for a person to enter. A more nature-centric definition for a cave includes narrow, deep cracks in rock

Large rock formations, known as cave bacon, in Shasta Caverns, California. These structures are formed by deposits of dripping water in subterranean caves.

A small cave along a limestone outcropping on Mount Charleston, in Nevada. Structures like these often provide wildlife with areas for sheltering, nesting, and denning.

A Cascade Caverns Salamander (*Eurycea latitans*), which is endemic to the cave system it is found in near San Antonio, Texas.

outcrops, areas under large fallen rocks, long erosional pockets common in sandstones, and iconic large caverns (like Mammoth Cave and Carlsbad Caverns), and only rules out spaces the wildlife species could not fit into. Animals that use caves and that have also adapted to areas with human development often shelter in crawl spaces, attics, chimneys, culverts, and sewers. For folks who want to support species that use caves, hollow areas can be created for quite a few species. Artificial caves can attract animals away from dwellings that might be less suitable for wildlife to shelter in.

Key characteristics of a well-designed cave include good insulation, appropriate size for wildlife, appropriate placement for use, and rough, textured ceilings and walls for animals to climb; a cave suitable to live in does not flood (unless it always has water, such as a cave next to a pond). Insulation can be from deep soils, mulch, or thick stones outside the structure to keep the cave cooler than the outside temperatures in summer and warmer than winter lows. Note that these created spaces are similar to burrows. The size of the cave will depend on the species it is meant to support, which will also depend on the overall yard size. Raccoons and foxes, for example, should have caves that are 4 to 5 feet (1.2–1.6 m) deep in colder regions like zones 2–6, but openings and tunnels can be 14 to 20 inches (0.35–0.45 m) in diameter. Smaller animals, like salamanders, will use much shallower caves with openings that are less than 3 inches (7.5 cm) in diameter and need damp conditions. Placement is also important, as some animals will walk or crawl

continued overleaf

CAVES *continued*

into ground-level caves, but swallows and swifts will use caves with openings 8 feet (2.3 m) or higher off the ground.

Suitable materials for walls and ceilings include bricks, natural stones, animal kennel tops with a roughened interior, and durable plastic structures with deep scratches for climbing. Using cement or new cement blocks will work for reptiles and

A Tricolored Bat (*Perimyotis subflavus*) hibernating in a cave. During the summer months, these bats will seek shelter in dead leaf clumps of trees, tree hollows, and barns.

Organic Materials

— Leaf Litter

Many species of trees and shrubs drop their leaves seasonally. Plants that drop their leaves seasonally are known as deciduous. Some species drop their leaves during the dry season and droughts, while most species lose their leaves during winter. Deciduous plants provide crucial habitats and feed local nutrient cycles. In forested areas, the leaves typically make an even covering of the forest floor. Rain and snow help secure this leaf layer and prevent leaves from blowing around. In open woodlands, forest

mammals, but the pH can harm amphibians and invertebrates. Care should be taken to ensure spaces that include access to soils and organic materials if salamanders, toads, or other invertebrates are the target residents. In regions with harsh winters, areas of the cave should be higher than the entrance. This helps warm air stay in the cave and prevents water from soaking the shelter. See the chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters" for design ideas.

A common cement cavity protecting plumbing and gas valves, which also functions as a pit trap for many animals, including snakes.

edges, and savannahs, dropped leaves are carried by the wind into areas under bushes and branches, creating localized, secured piles of leaves. Rainstorms that wash leaves and other materials into local heaps can create similar piles. Although some animals, like gall wasps and leaf miners, are left to chance for their survival and where leaves fall, most animals seek out secured leaves in suitable microhabitats.

Leaf piles create immediate protection from weather and provide insulated spaces with more consistent humidity and less variation in daily temperature swings. As leaves decay, bacteria, fungi, and decomposing organisms consume the organic materials. Their metabolic processes that break down the leaves involve chemical reactions

Fallen leaves along a deciduous forest floor are part of the nutrient cycle the mycelium of this mushroom facilitates.

Leaf fall by a boulder that is deeper than nearby areas. These microhabitats provide shelter for many terrestrial and non-fossorial animals (those not adapted to digging) and overwintering sites.

that produce heat, which creates warmer microhabitats compared to the surrounding areas. Pupating butterflies and moths, overwintering insects, various amphibians, nesting mammals, and many soil invertebrates rely on these warmer microclimates for protection from extreme cold temperatures to survive the winter.

In urban areas, hard surfaces allow leaves to be blown around and washed into less wildlife-friendly piles that are also viewed negatively by most residents. These materials can clog important drains, create traffic hazards, and make surfaces slippery. Due to these hazards, many cities and landowners bag up leaves and remove them

Yard cleanup in suburban areas usually removes leaf litter and piles, removing wildlife and making it difficult for remaining organisms to find winter shelter. When possible, organic material should be kept on site to keep wildlife safe. If materials do need to be sent away, doing so in the growing season will allow for organisms to relocate if they can.

from the landscape entirely. Doing so removes key habitats for many of our wildlife species, many of which may have already nestled down in the piles. Although cleaning up spaces is important, keeping organic materials in the landscape helps encourage wildlife. Some options for keeping cleaned-up organic material around include creating local brush piles, relocating leaves to areas out of view, mulching landscapes with whole leaves, and compost piles. For more, see the chapter 2 section "Wood" and the chapter 4 section "Leave the Leaves."

— Wood

Wood is a vital resource in ecoregions that have shrubs and forested communities. Botanically speaking, wood is different than woody growth. However, for the purposes of this book, *wood* will simply refer to woody plant material, including typical tree roots and branches, bamboo shoots, and palm tree trunks. This does not mean, however, that the role of wood from one plant species is the same as another. For example, oak and pine trees have thick bark that peels away, which creates preferred pupating areas for some insects, while birch trees and palm trees do not.

As habitats transition, by either succession or disturbance, woody materials tend to remain in habitats for many years. Woody root systems break apart soils and, as they decompose, create nesting and overwintering sites for wildlife, including insects, amphibians, mammals, and reptiles. Standing wood structures, like hollow living and

A recent tree fall exposes nutrient-poor soils below while creating vertical soil faces on which plants and animals can get established. The trunk creates new shelter resources and food resources for wood-eating insects. Adding a tree fall to a garden design usually is not an option. However, intentionally providing similar resources is feasible and improves habitat for garden wildlife.

dead trees as well as large dead branches, often create shelter for birds and cavity dwellers. A large suite of insects and fungi feed on dead wood, which facilitates the local nutrient cycle. There is even a name for large logs lying on the ground undergoing their slow decay—*nursery logs*. As wood breaks down, nutrients are slowly released into the surrounding area, and the wood begins to retain water. This localized increase in moisture allows more fungi and bacteria to grow, which increases the internal temperature of the wood and speeds up the nutrient cycle. With an increase

A Mountain Chickadee (*Poecile gambeli*) brings food to its nest in a tree hollow. Tree hollows are usually removed from developed areas. Adding bird boxes to designs provides similar resources that animals can take advantage of.

in nutrients, moisture, and temperature in the area, new plants have a better chance to establish, making the log a nursery for young plants.

Woody materials are also important for a variety of invertebrates. Some species feed on wood, some feed on the fungi that break wood down, and a large array of animals depend on the damp microhabitats that fallen wood provides. Logs and branches from thick-barked trees, like pines, oaks, and maples, provide refugia and pupating areas in the space that forms as the bark separates from the wood. Cavity-nesting insects, including many species of bees, nest in the tunnels excavated by other insects. Species that depend on dead or decaying wood at some point in their life cycle are described as *saproxylic*.

Outside of urban areas, woody resources cycle through a natural area as habitats grow and change. However, in urban settings, dead wood is typically removed. Luckily, it is easy enough to add to a garden. Visual spectacles can be designed using large logs or root crowns as focal points. Toppled trees often pull up root crowns that can also be used for centerpieces, although these are heavy and difficult to move. Equally stunning pieces can be made using dried-out, gnarled branches. More muted designs can incorporate log borders around garden beds and paths or can hide logs around bunchgrasses and herbaceous plants that grow over the logs. Whole or split logs

In Louisiana, a lizard peeks out of the shelter it has found in a dry, late-stage, decaying wood trunk. By understanding how organisms utilize space, we can intentionally provide these resources. With careful planning, animals can be encouraged to reside away from high traffic areas.

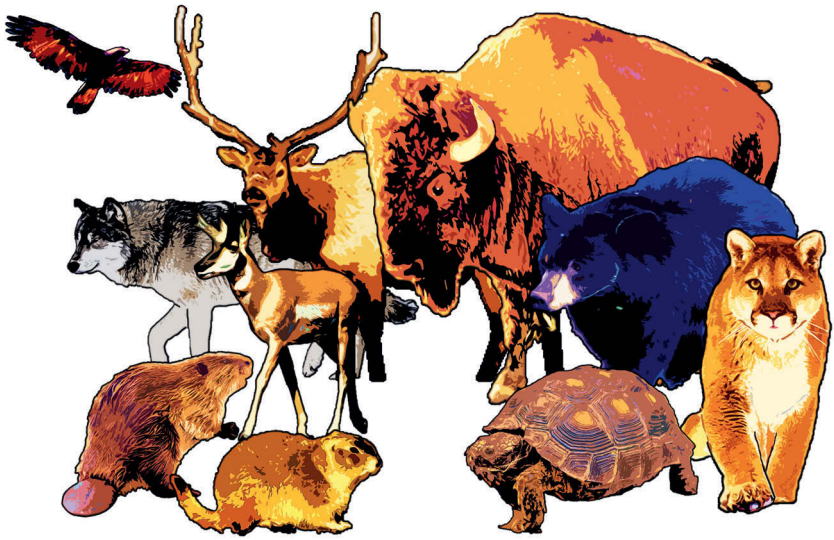
Wood ear fungi (order Auriculariales) fruiting body in a forested riparian corridor, in Oxford, Ohio. Fungi are important for nutrient cycles and support a variety of animals. Garden designs with downed limbs or organic-rich areas should allow various fungi to persist.

make great borders, tall pedestals, and planter centerpieces. Large branches are great for centerpieces as well, and both are easy to plant around. Designs can incorporate hidden, woody materials, like slow-compost piles and buried logs and old tree root crowns still underground. The most useful wood structures to add to urban areas are old branches and tree trunks that have not been chemically treated. As long as the chosen wood piece is more than 6 inches (15 cm) in diameter and 9 inches (23 cm) long, it will be used by insects, including wood-boring beetles and stem-nesting bees. As the wood breaks down, the bark will separate and create natural refugia for more insects, including pupating butterflies, moths, and overwintering bees.

Ecosystem Engineers

Around the globe, gardening with native plants is becoming a common tool for landowners to help out nature and return pollinators, birds, and other wildlife to our landscapes. It is true that as we fill more areas with native plants and keep them pesticide free, we increase local wildlife abundance compared to cement jungles and pesticide-laden lawns. However, many people, including professional restoration biologists, are under the assumption that planting native plants is the same as restoring native habitats. As the previous sections have laid out, there are many important characteristics that create habitats. In addition to native plants and abiotic factors, wildlife also fill a crucial role in maintaining and changing habitats.

To provide a better understanding of how plants and wildlife create dynamic systems that construct robust habitats, this next section will focus on the feedback systems of often-extirpated wildlife. Without question, it would be ridiculous and dangerous to suggest that anyone try to keep any of these species in their garden. In-



A diagram of just a few of the larger, often extirpated ecosystem engineers. Starting at the top left and moving clockwise: Golden Eagle (*Aquila chrysaetos*), Gray Wolf (*Canis lupus*), Pronghorn (*Antilocapra americana*), Elk (*Cervus canadensis*), American Bison (*Bison bison*), American Black Bear (*Ursus americanus*), Cougar or Mountain Lion (*Puma concolor*), Desert Tortoise (*Gopherus agasizii*), Black-tailed Prairie Dog (*Cynomys ludovicianus*), and North American Beaver (*Castor canadensis*).

stead, the following profiles are intended to explain important processes some wildlife cause and how to mimic those processes to create more robust wildlife habitats.

— Bears

Two species of bear were once common throughout Canada, Mexico, and the United States. American Black Bears (*Ursus americanus*) inhabited most of the forested ecoregions historically, with a few subspecies in the southern ranges. Brown Bears (*Ursus arctos*), which includes Grizzly Bears (*Ursus arctos horribilis*), historically inhabited the western half of North America from Alaska to central Mexico and from California through parts of the Great Plains. American Black Bears historically overlapped much of the Brown Bear's range, extended east to the Atlantic Ocean in forested regions, and were mostly absent from the Great Plains.

Both species are omnivores that were crucial to large-scale nutrient cycles and fleshy fruited plant-seed dispersal. On a continental scale, these two actions—the

Grizzly Bears (*Ursus arctos horribilis*) were once found across much of the western mountains of North America, but are now reduced to much smaller ranges. INSET: Bear (family Ursidae) range map.

damming of major salmon-habitat rivers and the killing of bears—destroyed a major system that was responsible for important nutrient inputs throughout the historic range of bears. This collapse is often overlooked in conservation and is further discussed below. Research on berry-producing plant establishment in bear habitat also showed that bears help create plant communities dominated by fleshy fruits. This effect is likely due to the scarification (the scarring or breaking of outer seed coats) of seeds during digestion and improved germination rates.

A Grizzly Bear (*Ursus arctos horribilis*) moving through a landscape that is drastically affected by its presence. Nutrient cycles, seed germination, soil disturbances, and broken branches are all affected by bear presence. We can replicate some of their roles to improve garden habitats.

In general, both bear species are crucial for seed dispersal and germination. Many plants in North America have seeds with thick coats. Gardeners and horticulturalists have figured out how to mimic natural damage to seed coats via scarification to improve germination rates. However, scarification can be very time-consuming; it is necessary to handle each seed and ensure the seed coat is damaged deeply enough to ensure water can penetrate, but not too deeply that plant embryos are damaged. Instead, innovative gardeners and conservationists have begun collecting bear scat for plant reproduction. A single pile of bear scat can sprout over a thousand new plants, many of which need scarification to develop. By using seeds that have passed through a bear's gut, germination rates are increased, and preparation time with seeds is reduced. The downside to this approach is that plants must be identified and sorted after germination.

Bears are incredibly important in cycling marine-derived nutrients from migrant fish into local vegetation communities. In addition to bear population declines,

Fungi and vegetation emerge from a fecal pile left by an American Bison (*Bison bison*). Large mammal scat adds vital nutrients to habitats; it can be mimicked in gardens by adding manure.

An American Black Bear (*Ursus americanus*) sits perched among hawthorn (genus *Crataegus*) berries. Black bears are important seed dispersers, and their populations are growing once again.

damming of rivers and pollution have drastically interrupted these nutrient cycles, preventing marine fish that gain mass in the oceans from migrating inland to reproduce and eventually die. One study found that Brown Bears feeding on salmon increased nearby soil ammonium (NH_4^+) concentrations three-fold and nitrous oxide (N_2O) flux by 32-fold. Soil carbon dioxide (CO_2) flux, nitrate (NO_3^-), and nitrogen transformation differences were, however, negligible. A 20-year study that added salmon carcasses to one riverbank confirmed the presence and increase of marine-derived nutrients in soils on the enhanced bank. However, that study also found that plant-available inorganic nitrogen and nitrogen transformation rates were mostly unaffected on the salmon-enhanced bank. The flaw in this study was that it did not compare the vegetation communities, which after 20 years could easily have bacteria and plant communities utilizing all of the available nitrogen throughout the year. This study also removed a major part of the nutrient cycle that would occur through digestion by bears. Either way, the additional nitrogen enters the nutrient cycle eventually, enhancing local communities and fertilizing inland habitats, which is important to replicate with natural fertilizers in areas where bear populations and rivers have been negatively impacted.

Foraging bears regularly break open decaying logs and turn over objects like stones, wood debris, and man-made objects. Disturbed stones and logs can create new shelter areas for other wildlife, like salamanders, skinks, and insects, by increasing space under the object that animals can access. Logs that have been broken open by bears expose insects that birds can forage on, and birds can also spread the organic material and nutrients around the area. Other omnivores also move objects; however, they are not as strong as bears. Without the disturbance from bears, larger stones and logs settle into the soil, reducing the amount of shelter for smaller wildlife, which can affect their population sizes and risks of predation.

An American Black Bear (*Ursus americanus*) stands on downed logs. When older wood has lots of insect grubs inside, black bears will tear apart the logs to feed on the protein-rich insects. Moving objects in their habitat creates new sheltering and feeding resources for other animals in their range.

Re-creating some of the key roles bears have in an ecosystem creates healthier plant communities and more habitat for other wildlife. Spreading manure and watering with nutrient teas every few years facilitates the lost nutrient cycles. Tipping stones and logs every few months prevents them from settling and creates more areas for small wildlife to shelter. Similarly, adding untreated wood chips mimics logs broken by bears. More details on how to mimic roles of bears in the landscape are presented in chapter 2.

— North American Beavers

Up until the 19th century, most riparian areas across North America were inhabited by the North American Beaver (*Castor canadensis*), which has 24 subspecies. However, beaver populations have been severely reduced, by both hunting and habitat loss, and their reduction has had landscape-level repercussions. Beavers are incredibly important ecosystem engineers, and their absence and presence strongly affect habitats and natural cycles. Beavers are semi-aquatic and regularly build dams in streams, which creates water impoundments like ponds and lakes. Their dams reduce stream velocity, retain stormwaters, create wetlands, and increase overall water retention of the watershed. Wetlands in general help recharge groundwater by allowing the water to infiltrate from the surface and elevating the local water table, which affects seasonal springs. Reduction of stream velocity and retention of water during storm events help prevent major flooding downstream and reduce erosion.

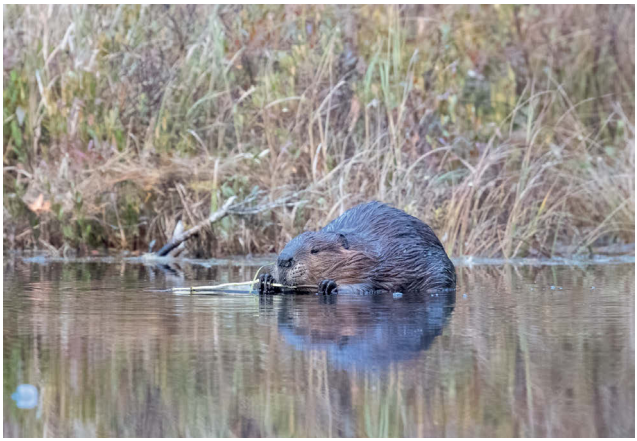
A North American Beaver (*Castor canadensis*) along the edge of its pond.

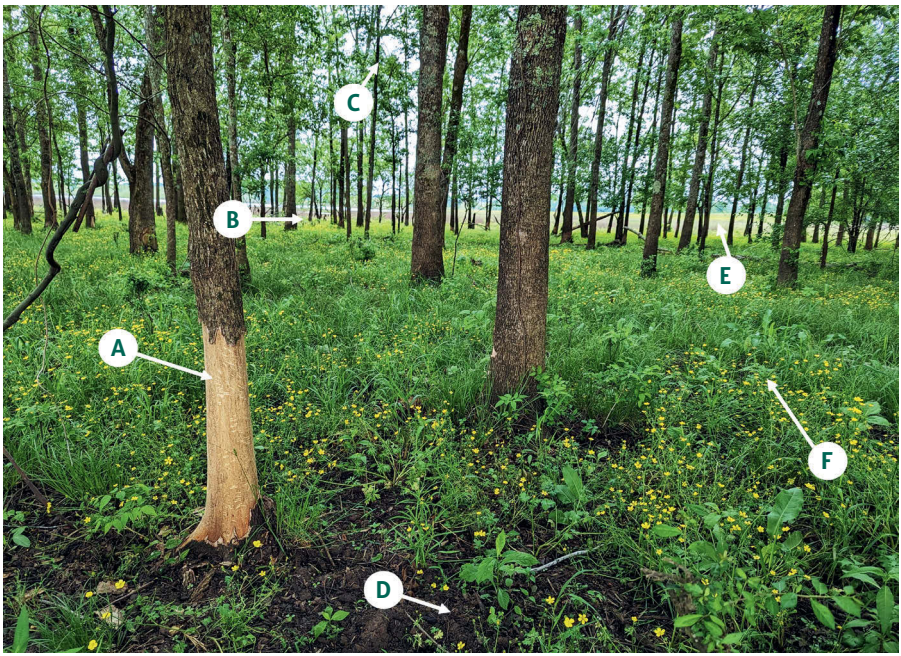
An adult damselfly (suborder Zygoptera), which is often seen flying about wetlands. Their larvae live in aquatic ecosystems, and many species greatly benefit from beaver activity.

Wetlands and riparian areas in general are important habitats within a landscape. Some of the major roles of wetlands and riparian corridors include being habitat for wildlife, functioning as natural firebreaks and refugia during fires, and facilitating nutrient cycles. When beavers create wetlands, their ponds are often near wooded areas and tend to be between a foot (30 cm) and 6 feet (1.8 m) deep. These depths promote the establishment of aquatic vegetation and underwater habitats. Many amphibians utilize these ponds for parts of their life cycle, as do many insects. Over time, water impoundments alter the local topography. When the velocity of water is reduced, sediments and organic materials are able to settle and accumulate, filling in low spots and evening the soil surface. These soils are generally nutrient-rich, allowing vegetation to establish and grow. Vegetation in low-velocity streams and wetlands helps keep waters cool by blocking sunlight, which also helps the water stay oxygenated for fish and invertebrates. Conversely, larger impoundments often become warmer than nearby free-flowing streams, which can be beneficial for some amphibians and insects, but detrimental to some fish, such as trout and other aquatic wildlife. In hilly and mountainous regions, dammed streams turn into picturesque, vegetated step-pool waterways that provide breeding habitat for amphibians and some fish, while reducing habitat for wildlife that depend on fast-moving waters.

As beavers build their dams and lodges, they also help thin out woody vegetation by cutting down smaller trees. Their diets are vegetarian, and they actively feed on

A beaver chews on vegetation in a wetland it has created. Replicating beaver activity is more than making wetlands. It includes clearing out dense vegetation, preventing new woody plants from establishing, and piling woody debris.





After a North American Beaver (*Castor canadensis*) family was removed from a nearby lake in Alabama, water levels dropped, and a terrestrial plant community is beginning to establish in the area again. During their stay, beavers girdled and killed trees while feeding on the bark. Young trees were removed to build their hut and dam, leaving an open stand of trunks. (A) Trunk girdled by beavers, which killed the tree. (B) Absent shrub layer. (C) Open canopy letting dappled light through. (D) Nutrient-rich soil and organic debris. (E) Upland area not affected by beaver flooding. (F) Herbaceous plant community establishing.

some tree species, aquatic vegetation, grasses, and forbs—activity that opens up forest canopies and understories. Open canopies allow dappled light to reach the ground and water, promoting more plant growth. Beaver lodges are constructed with wood and mud, and have at least two chambers. Lodges are generally built in shallow water along banks, with the entrance underwater, but can also be found along shores. Studies conducted in Lithuania showed a variety of small mammals also living in and around beaver lodges, which is likely true for North America as well.

Once beavers are displaced or die, their logjams deteriorate, and much of the created wetland complex drains. Once water recedes and soils dry out, the wetland plant communities die off, and the built-up soils from the wetland begin to support upland vegetation communities. Fluctuations of lands between wetlands and uplands is crucial to creating a shifting landscape and natural habitat succession. In addition to creating wetlands, beaver activity creates important snags and roost areas for wildlife by killing tall, robust, mature trees. Snags are preferred nesting locations for Bald Eagles, Osprey, and many large wetland birds. Without beavers, conservation efforts for birds that naturally utilized large dead trees now typically include building tall platforms for nests and rookeries, because the natural process has been severely limited. Fortunately, beaver populations are quickly rebounding because fur trapping has lost its popularity and people are trying to better coexist with these beneficial animals, although suburban areas usually are not able to support beaver activity.

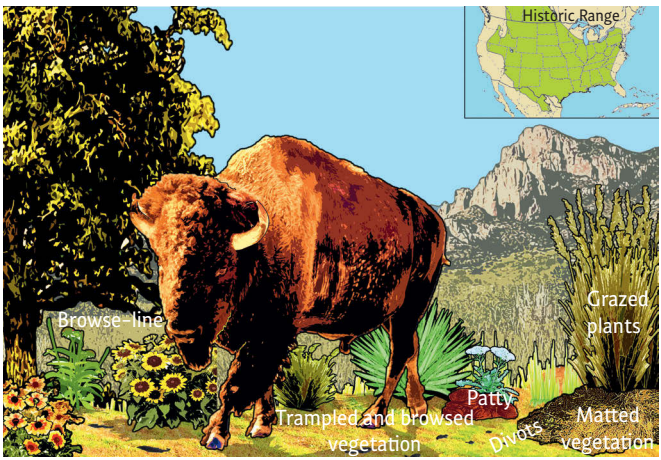
In developed areas, recharging groundwater and elevating the water table can be particularly beneficial because water infiltration is drastically reduced by soil compaction and expanses of impervious surfaces. Even so, as beavers repopulate their historical range, they are entering suburban and urban areas, leading to wildlife

A stormwater mitigation installation in Salem, Oregon, that replicates the role of North American Beavers (*Castor canadensis*) by allowing waters to pool, then dissipate slowly. This prevents floods downstream and creates habitat for wildlife.

conflicts. Urban areas are rarely designed to allow streams and stormwater drainages to be dammed. Damming urban waterways can easily lead to flooded backyards and basements, property damage, and overall problems for local communities. The effects of beavers on a local scale generally affect many acres, which means there is not a great way to mimic their impacts on habitats in a developed environment that never planned for them. However, rain gardens and water catchments can easily be built and integrated into developments, allowing stormwater to stand long enough for amphibians to breed and water to soak into the ground, recharging the groundwater. See the chapter 2 section "Rain Gardens and Bioswales" for more information.

— American Bison

Historically, American Bison (*Bison bison*) were present for at least part of the year from the eastern Sierra Nevada and Cascade Range all the way to the Atlantic states, and from northern Mexico to central Canada. Atrocious acts by settlers and governments have reduced their range to just a few small, managed populations that are unable to migrate. Estimates of earlier bison population numbers have an incredible range, with a commonly accepted estimate of around 65 million; lower estimates are around 20 million, and higher estimates are near 10 billion bison living in North America prior to the slaughter by Europeans. Where bison used to roam, many plants are tolerant of—if not dependent on—the nutrient cycles and disturbance bison facilitate. On a landscape scale, bison mostly consume grass species and avoid many of the showy, flowering plants. In doing so, bison influence local plant biodiversity, promoting non-grass plants by actively not feeding on them.



American Bison (*Bison bison*) affect the ecosystem in many different ways that facilitate resources that other wildlife use. Browsing grass helps promote flowering plants, patties feed nutrient cycles, and trampled plants provide three-dimensional structures and dense vegetation mats near the ground.

A herd of American Bison (*Bison bison*) stands next to the trampled and laid-down vegetation where they had been resting. Their interactions with the landscape create important habitat resources for many other organisms. The crushed stems and leaves provide thermal insulation for the ground and cover for small wildlife, seedlings are able to reach the sunlight quickly when vegetation is trampled, and the remaining standing vegetation creates windbreaks.

While herds moved across the landscape, their hooves trampled plants, their bodies pushed over tall shoots, and their teeth cut down grasses, affecting the overall structure and makeup of their habitats. Based on observations of herds today, bison ignored new growth while consuming the previous season's growth. During winter, bison pursued perennial forage and cleared away snowbanks to access plants. Vegetation was also broken and pressed to the ground when the animals would lie down to rest. Likewise, their presence also affected nutrient cycles. Massive excreted bison patties spread seeds and fed various insects and soil organisms, which in turn improved local nutrient availability.

Another behavior of bison that drastically affects the local vegetation community is scratching. Anecdotally, these massive mammals are very itchy, and they will use almost anything to scratch. This includes fence posts, cement pillars, sides of buildings, and natural features like tree trunks, sturdy bushes, and stones. Bison will also rub their horns on trees and saplings, as will deer and Elk, which often kills young trees. These behaviors can prevent woody plants from establishing, uproot some plants, and knock over already dead trunks, which facilitates the persistence of grasslands and meadows.

Wet soils can also be affected by bison as their massive bodies are supported on two or three hooves at a time. This distribution of weight causes deep depressions in the soils. Deep hoofprints aerate soils and facilitate nutrient cycling, and they create cool shelters that hold water. Small amphibians, various insects, and other tiny

A herd of American Bison (*Bison bison*) moves through a shrub patch, browsing on old grasses and dropping patties that feed local nutrient cycles. This also breaks weak branches, knocks over withered vegetation, and stirs up insects for birds, which can be seen flying in this photo.

organisms can be found in wet hoofprints hydrating and escaping the heat. Cattle ranchers using holistic practices say deep hoofprints from cattle help native plants establish, but there are currently no scientific studies on this pattern. Bison also create new, large areas of standing water or wallows. Studies looking at newly introduced herds in Oklahoma observed animals avoiding the existing depressions in the landscape. Instead, they would form new wallows, which creates new wetland habitat and affects local water availability for animals in the landscape.

Disturbed soils from bison and other large animals create critical habitat for many plants. For example, the rare annual, tiny Cryptanthe (*Cryptantha minima*) lives only in dry, mixed-grass prairies and needs periodically disturbed soils to germinate. Running Buffalo Clover (*Trifolium stoloniferum*) was once thought to be extinct after bison were eradicated in its range, but were rediscovered in an area with soil disturbance in the 1980s. There are likely many more plants and animals that are dependent on bison disturbances, but due to the severe reduction in their populations and range, it will be difficult to connect these relationships.

The extirpation of bison has drastically augmented local landscapes, habitats, and nutrient cycles where they were once abundant. Fortunately, land managers, tribes, and conservationists are reintroducing these keystone species, although slowly. In the absence of these massive animals, there are practices that can be adopted by land

American Bison (*Bison bison*) hoofprints in a drying ephemeral pool. These depressions often host young frogs and toads seeking out moisture as their larval habitat dries out. Similarly, many insects puddle, hydrate, and collect mud from these small pools. Divots like this provide some escape from the summer heat, which is why it is important to add a few similar pockets to wildlife gardens without large mammals.

managers and gardeners to emulate the ecological roles of bison, including clearing snow, pruning vegetation from the previous year, and fertilizing. (See the chapter 2 section "Replicating Absent Grazers.")

— Elk

Before Europeans arrived, Elk (*Cervus canadensis*) were widely distributed in North America. They inhabited ecoregions from the Atlantic coast to the Pacific Ocean, and from Mexico to northern Alberta, Canada. Estimates of their historical populations

A Blanchard's Cricket Frog (*Acris blanchardi*) hides in the deep shelter made by a cow hoof. American Bison (*Bison bison*) make similar holes, which are crucial for developing amphibians as their larval habitat dries out.

A herd of Elk (*Cervus canadensis*) in an upland herbaceous plant community. Their large size alone has drastic local effects, from broken stems under sleeping Elk to browsing. INSET: Elk (*Cervus canadensis*) range map.

put their numbers around 10 million. Today, their populations are isolated and have rebounded to around 1.2 million from their lowest counts in the early 1900s. Many of these isolated populations are privately managed for hunting, but major herds also exist on public lands. An Elk's home range is roughly 38.6 square miles (100 km^2), and herds can be locally migratory, meaning they move up to a few hundred miles between seasons.

Elk are quite adaptable in both the food they consume and the areas where they live. In the Great Plains, populations commonly have diets high in grasses and forbs, whereas Elk in the Pacific Northwest consume varying amounts of deciduous and coniferous trees and shrubs, in addition to grasses and forbs. The vegetation Elk consume also changes throughout the year. Across the continent, herds can be found occupying open prairies, savannahs, and open forests. They are known to prevent woody encroachment into areas, as they consume stands of aspen, cottonwood (both genus *Populus*), Red Alder (*Alnus rubra*), and willows (genus *Salix*), especially during seasons of limited availability of other forage. Elk feeding habits are known to shift after fires, as the animals target plants in previously burned areas, likely due to the nutritious new growth. This means that Elk help maintain post-burn herbaceous plant communities by keeping woody plants suppressed for a few years, as well as feeding on herbaceous plants they find tasty.

Studies of plant community structure found that the exclusion of Elk resulted in rapid increases in the density of young deciduous woody plants. Although this is great for plant biodiversity, it also means that open areas in forests and grasslands fill in without Elk. Open understories are important for some birds and bats that for-

Large Elk bull (*Cervus canadensis*) with two females feeding and browsing.

Two Gray Wolves (*Canis lupus*) walk through their habitat in Yellowstone National Park, in Wyoming.

age in flight. Similarly, creating overstories on grasslands leads to habitat succession. Without Elk or other large grazers browsing plants, the establishing shrublands have higher stem density and denser vegetation matrices.

Replicating Elk feeding behaviors in your garden is likely already occurring through pruning and weeding. Elk help keep woody plants from colonizing areas as well as open up forest understories. Cutting back woody plants and preventing them from growing into areas replicates the influence of Elk on an area. Much like American Bison, Elk are also responsible for trampling herbaceous plants, bedding down in vegetation, and removing snow cover, which allows the exposed soils to further cool in the winter. Clearing paths, breaking old herbaceous stems, exposing soils in winter, and trimming up plants further mimic the presence of Elk in any area.

— Gray Wolves

Historically, Gray Wolves (*Canis lupus*) were common from Mexico to Alaska, but today they are found in only a few locations. Ecologically, Gray Wolves are important

because their presence affects plant communities, food availability for other animals, and nutrient cycles. Removal of wolves from ecosystems has allowed some herbivore populations to grow so large that plant communities are negatively affected. For example, in Westchester County, New York, deer populations are consuming and killing many of the native plants, while avoiding the less tasty invasive plants. This is causing a feedback loop that promotes invasive plants in the wild and actively removes native plants.

Habitats with predators are sometimes described as fear landscapes, based on the theory that prey animals change their behavior when predators are around. Data show that prey species avoid areas in the landscape where they are more vulnerable to predation. One of the more famous examples of this comes from wolf reintroduction into Yellowstone National Park (USA). After wolf reintroduction, vegetation communities began to change, especially in riparian areas. Some researchers suggested the changes were due to herbivores avoiding areas where they could not keep an eye out for wolves, which allowed plants to regrow and not be browsed. These data point toward a fear landscape; however, fire ecologists have argued that a large forest fire that occurred around the time of the reintroduction also affected where herbivores were feeding. The two events likely had a synergistic impact, which allowed overbrowsed plant communities to rebound.

In addition to Gray Wolves affecting where prey animals feed and roam, they also affect prey behaviors like running, stampeding, and huddling up. Although there are no studies published that look at the damage done to plants by fleeing prey, it can be deduced that plants would be more readily broken by the force of a fast-moving, large animal relative to it walking. Similarly, when animals flee, their paths often cut through areas like tall shrubs or thorn scrub that they generally avoid while walking or feeding. Prey species that typically live in herds move differently when predators are near and huddle together. Soils and plants are affected when prey animals group together, which increases trampling, compacts soils, breaks more branches, and presses aerial plant material into the soil. Defecation and urination lead to localized spikes in nutrient deposits, which would benefit some plant species during establishment. Although Gray Wolves aren't directly causing these impacts to their habitat, their presence is responsible for the changes.

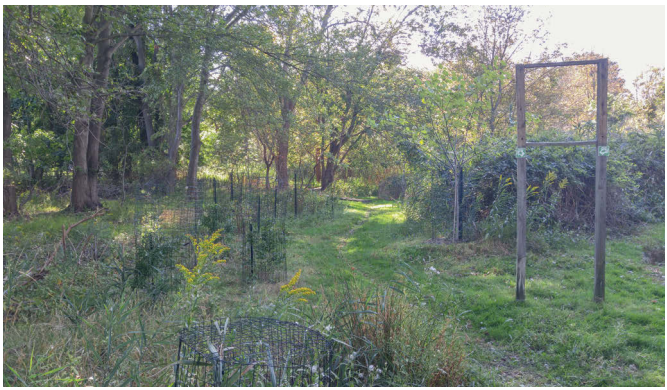
This paragraph and the next discuss the feeding behaviors of wolves, with some graphic descriptions of carcasses left by wolves and roadkill. If this interests you, please keep reading; if it does not, skip these paragraphs. Animals that scavenge on dead animals are also affected by Gray Wolves. If you have ever driven along roads in less-developed areas of North America, you have probably seen large roadkill that is untouched by Turkey Vultures (*Cathartes aura*), crows (genus *Corvus*), and even Coyotes (*Canis latrans*), even though it clearly has been there for a few days. Similarly, you may have seen other large roadkill that was clearly picked over. The difference

A Downy Woodpecker (*Dryobates pubescens*) and a chickadee (genus *Poecile*) feed on suet. Suet mimics fats, which would be available on carcasses taken down by wolves and other predators as well as on insects in snags.

between these two roadkill states is related to Gray Wolves and the state of the animal after it was hit. When Gray Wolves take down prey, members of the pack tear the carcass apart, often removing limbs and exposing bones and tissue. This allows vultures, crows, ravens, and other scavengers that cannot tear into the carcass to access the meat and further consume the prey before it spoils. Exposed tissues are also able to dry out more quickly, and in winter months, dried, unspoiled fats, similar to suet, are eaten by various birds and even some mammals.

With wolves removed from our ecosystems, many prey animals die from sickness or old age, with their skin mostly intact. This means that many of the animals that historically fed on the carcasses that wolves killed are no longer able to do so. Therefore, large carcasses are decomposing in place, with their nutrients being mostly cycled by insects and bacteria in a very localized space. Most often, soils beneath the large carcass obtain too many nutrients, and plants are unable to grow in the area until they dissipate or are consumed by soil biota. This is in contrast to the historically common event of large animals being mostly consumed and spread out across a kill site by wolves and smaller scavengers. In turn, nutrients were dispersed across the landscape in a way that allows plants to re-establish or continue growing. To put this in perspective, researchers studying American Bison herds on the Konza Prairie, in Kansas, estimated that annual bison mortality (without wolves) inputs approximately 11,000 pounds of organic matter per 250 acres (or 5,000 kg per 1 km^2). Approximately 1% of the organic matter decomposing and continuing in the nutrient cycle is from bison, while the other 99% is plant material.

In the absence of wolves, large animals often decompose in place instead of being consumed by wolves, mesocarnivores, and scavengers. This leads to localized nutrient burns, where salts, fats, and chemicals from a carcass prevent water absorption by plants and require time and precipitation to dilute before plants can establish again.



Deer exclosures around native plants on a preserve in Mamaroneck, New York. These allow native plants to grow without being killed by overbrowsing or antler rubbing, while also providing forage for deer (family Cervidae).

Emulating the effects of wolves in urban environments is not something that can be easily done; however, some of the resources wolves create can be managed or re-created. See the chapter 2 section "Replicating Absent Predators." In areas where deer and other herbivores are overpopulated, protecting plants with wire cages, fences, and other barriers (aka exclosures) help native plant communities. Make sure to read through the "Wildlife-Friendly Fences and Barriers" section in chapter 2 before installing protective structures around plants.

— Prairie Dogs

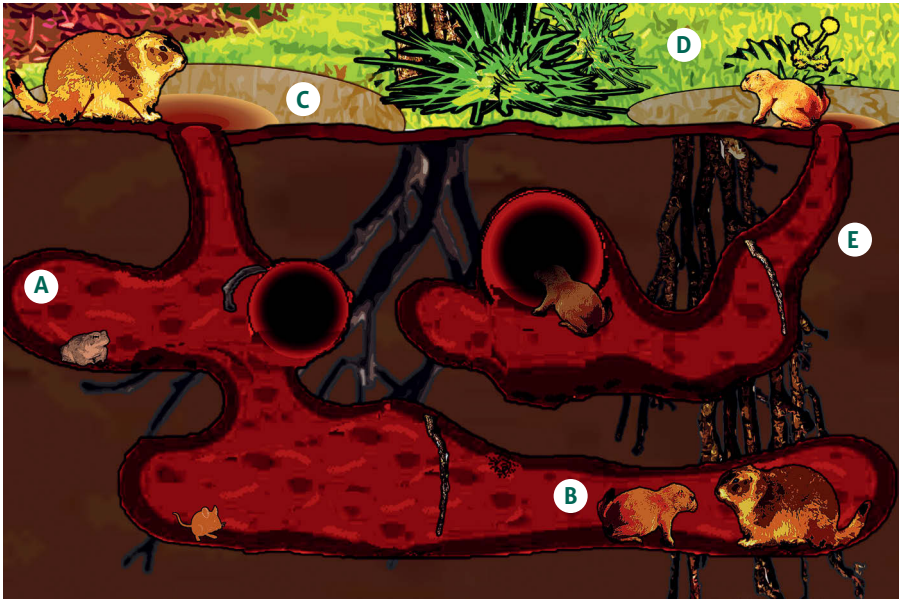
From the eastern Rockies through the Great Plains, a prairie dog (genus *Cynomys*) town used to be a common sight. However, western agricultural practitioners saw

A prairie dog (genus *Cynomys*) sits at the entrance to one of the burrows leading to a massive underground network of tunnels. Bare soils around the entrance provide dust-bathing resources for birds, foraging areas for seed eaters and insectivores, and areas for new plant establishment. INSET: Prairie-dog (genus *Cynomys*) range map.

these animals as a menace and poisoned most populations. Prairie dog towns, however, host over 200 species, including Burrowing Owls, toads, and salamanders, while also supporting a wide range of both abiotic and biotic ecosystem services. Numerous studies show that areas with prairie dogs have faster groundwater recharge, better regulation of soil erosion, improved soils, and enhanced forage availability compared to grasslands or shrublands where prairie dogs are no longer present.

A prairie dog town consists of an abundance of tunnels and underground chambers that can occur throughout many acres, depending on the number of prairie dog families present. Tunnel entrances are between 4 and 12 inches (10–30 cm) in diameter, reaching 5 to 10 feet (1.3–3 m) in depth and up to 35 feet (10 m) in length. On the surface, entrances typically have a ring of barren soil, which can extend more than 3 feet (1 m) from the tunnel, caused by both the deposition of excavated soils and prairie dogs feeding.

In suburban areas, it is understandable that folks are not keen on the idea of large tunnels popping up in the landscape or 6-foot-diameter barren circles forming in their yards. Similarly, perfectly re-creating a prairie dog tunnel, let alone town, would require an immense amount of work and space. However, we can re-create the results of specific prairie-dog characteristics to better support local wildlife. Of the more than 200 species that are known to use prairie-dog tunnels, most are simply seeking insulated shelter. Landscape designs can easily incorporate underground structures that provide thermal insulation, with sturdy walls and ceilings that only need to be 2 feet (60 cm) deep. Designs with barren soil patios and pathways mimic tunnel entrances and provide hunting grounds for birds and other animals. Maintaining plant structures with trimming and increasing plant diversity also help restore the diversity that prairie dogs support in wild settings.



Prairie dogs (genus *Cynomys*) create massive underground structures that are used by numerous species. Their galleries provide shelter for animals like toads (A) and places for them to shelter and den (B). Aboveground, they feed on vegetation and deposit soils (C), which provide hunting areas for wildlife and clear views of potential threats. (D) Farther away from their burrows, vegetation is heavily browsed and kept short, similar to mowed urban environments. Soils are aerated and roots are clipped as tunnels are built (E).

— Pronghorns

An icon of western North America, herds of Pronghorn antelopes (*Antilocapra americana*) were once common. Today, herds are just a fraction of their historical sizes due to hunting, urban expansion, roads, cattle, fences, and energy development. Currently, Pronghorns occur in roughly three-quarters of their historical range, which is better than many of the other animals discussed so far. There are also public and private programs actively trying to help their numbers rebound. Even though Pronghorns can still be seen throughout most of their historical range, these animals stay away from developed environments and are functionally absent from quite a few areas within their range.

Unlike American Bison and bears, Pronghorns are not known to be major seed dispersers via their diets. However, they do consume a wide array of plants, which shifts seasonally. During the winter and spring, they feed primarily on grasses and forbs. Woodier plants, however, are their main food staple in summer and fall, including sumac species (genus *Rhus*) and prickly pear cacti (genus *Opuntia*). This means that

Two Pronghorns (*Antilocapra americana*) stand in one of their habitat types with open grasslands between shrubs. INSET: Pronghorn (*Antilocapra americana*) range map.

Pronghorns are effectively pruning the active growth of grasses and herbaceous plants in spring, while in summer and fall, their feeding cuts back shrubs. In the winter, their feeding behavior helps remove dry and dead vegetation of grasses, which helps light reach the ground and thus promotes new plant growth and sprouting seeds in spring.

For native plants in gardens occurring within the range of Pronghorns, replicating Pronghorn feeding behavior is simple. Cut back herbaceous plants once in the late spring, shape and prune native shrubs in summer or fall, and clear out dead vegetation in early spring to help light reach the soil. Remember to keep the removed organic material on your property. More garden-maintenance activities are explained in chapter 2.

— Woodchucks

Woodchucks (aka Groundhogs; *Marmota monax*) can be found across Canada and throughout much of the eastern United States. They excavate burrows up to 24 feet

Aerial view of Pronghorn (*Antilocapra americana*) habitat in New Mexico.

A Woodchuck (aka Groundhog; *Marmota monax*) climbs a plant in its home range.
INSET: Woodchuck (aka Groundhog; *Marmota monax*) range map.

(7.3 m) long, but their burrows are often much shorter. Depending on the ecoregion, tunnels can be a few feet deep, with deeper tunnels occurring in colder regions. Woodchucks excavate a few burrows throughout their lifetime. In active seasons, burrows typically have side galleries and multiple entrances. One of the side galleries is for nesting and is insulated with dead leaves and grasses. There is also a chamber for defecation and urination. Nearby, young Woodchucks excavate tunnels that can be a few feet deep but are rarely occupied. In winter, some Woodchucks build a separate hibernation burrow that extends below the frost line. Unlike most other mammals, woodchucks enter a true hibernation state, so creating a space that maintains appropriate temperatures and stays dry is crucial.

Little research has been conducted on which other wildlife utilize these practice burrows, active burrows, and abandoned burrows. However, based on studies that have focused on burrows from other animals, there is likely a long list of animals that depend on Woodchucks for creating suitable shelters for both winter and summer activities; likewise, many animals and plants likely utilize recently excavated soil. Measurements of soil volume brought to the surface showed an average of nearly 400 pounds (297 kg) per tunnel. Such soil is locally distributed, building microtopography and new spaces for plants to grow.

Studies conducted in Connecticut showed that Woodchucks decreased the amount of grass vegetation around their burrows, which led to an increase in forb vegetation. However, they also selectively ate native grasses, which increased nonnative grass abundance. From an ecological perspective, the presence of Woodchucks

A Woodchuck (aka Groundhog; *Marmota monax*) outside its burrow, with fresh excavated soils covering local plants.

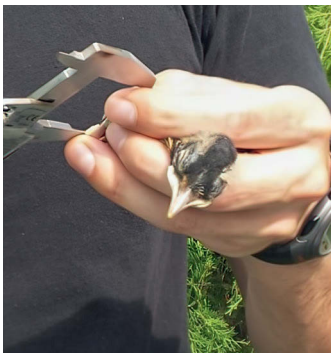
in large tract of lands would benefit pollinators and the overall local ecosystem. In more developed areas, however, it can be dangerous to have large tunnels popping up in the landscape. As with replicating prairie dog tunnels, landscape designs can easily incorporate underground shelters that provide thermal insulation and have sturdy walls and ceilings that only need to be a few feet deep and extend below the frost line. See chapter 2 for burrow designs.

— Other Extirpated Wildlife

The term *shifting baseline syndrome* is used to explain humans not realizing the drastic changes occurring around us over long periods of time, like a few decades. Ecologically, most people have not noticed the decrease in animal abundance that has occurred in their own lifetime. However, most folks can understand some of the loss when specific metrics are examined. For example, many folks born before 1980 can recall windshields covered in dead bugs after a long day's drive. Today, most folks can drive for weeks before needing to clean any insects off their windshields. Although some of this has to do with the improved aerodynamics of cars, the decline of bug splatter is mainly due to a loss of insect abundance.

Scientists have been compiling data that show overall declines in animal populations. What they are finding are disturbing, drastic losses in animal abundance. North American bird populations have declined by roughly two-thirds since the 1960s. That means that, right now, for every bird you see, there were two more in the landscape just 60 years ago. Insect declines are occurring at different rates, with the most severe in urban and suburban areas. Even though we might expect to see declines of insects in these areas due to habitat loss and pesticide use, studies in remote habitats (i.e., alpine meadows, protected wilderness, and even nature preserves)

A frog peeks out of a small garden pond. While this is a success for the homeowner, it is unclear whether the frog population will grow with this resource.



ABOVE LEFT: An American Robin (*Turdus migratorius*) collects material for its nest in an unintentional resource provided by an urban lawn.

ABOVE RIGHT: A researcher, Dr. Loren Merrill, collects data by measuring bones and appendages.

are also seeing steep declines in insect abundance over the past few decades. Every group of animals that has been studied so far has shown decreases in abundance in the last 100 years or less. Even worse news is that no groups of animals have seen an increase in abundance, but a few select species have increased their numbers.

The overall loss of abundance is important to consider when we design habitats and create benchmarks for our success. Many gardeners who create habitat for wildlife measure their success by the presence of wildlife in their planted area. A better mark for success would be wildlife successfully producing new members of their population. Another measure would be that habitats and wildlife are healthy and not filled with diseases and failing to reproduce. However, these latter two goals require

Wood Duck (*Aix sponsa*) shelters are commonly added to wetland habitats to promote their populations. Their natural nesting habitat is hollow snags, but these resources are often removed from the landscape.

some monitoring and a better understanding of what a healthy habitat is. By re-creating some of the processes proposed by ecosystem engineers, gardeners are more likely to have healthy habitats.

Numerous animals have been extirpated from most folks' landscapes. Understanding each animal's impacts on a landscape, especially how each species can affect other species, will assist in managing healthier landscapes. These healthier landscapes should in turn promote wildlife populations that can live in our neighborhoods.

— Burrow Builders

Nine-banded Armadillos

Nine-banded Armadillos (*Dasypus mexicanus*) have strong populations in non-urban areas of the Southeast. New research shows that what we once thought of as a single species is actually four different species with very similar looks and behaviors. Their range extends from the mid-Atlantic to Kansas, and south through Mexico and Central America. Most often, they can be found in grasslands, open

In Monahans, Texas, a Common Side-blotched Lizard (*Uta stansburiana*) stands in front of the abandoned rodent burrow it has claimed as its own. Lizards in this area are dependent on burrows made by rodents to escape the summer heat and hibernate.

A Nine-banded Armadillo (*Dasypus mexicanus*) ruts through leaves, searching for food. Recent research suggests that this species, which was thought to occur in North and South America, is really four genetically distinct, yet visually similar species.

forests, and shrublands. Within a single territory, an armadillo can have as many as 10 active burrows that it has excavated and maintains. These burrows are typically oval and, on average, 8 inches (20 cm) wide, 6 inches (15 cm) tall, and 20 inches (50 cm) deep (often deeper). The deepest tunnel recorded was over 15 feet (4.5 m) deep. Although armadillos are much less studied than other major burrowing animals in North America, data show that more than 40 animal species utilize armadillo burrows and disturbed soil areas for sheltering and hunting. Loosening soils and installing burrows of similar size in gardens helps replicate the microhabitats these animals create.

North American Tortoises

Across the southern latitudes of the United States and northern areas of Mexico, large tortoises used to be abundant. However, habitat loss and the pet trade have

An endangered Desert Tortoise (*Gopherus agassizii*) in its natural habitat. INSET: Tortoise (family Testudinidae) range map.

drastically reduced their numbers. Gopher Tortoises (*Gopherus polyphemus*) inhabit areas in the Southeast and are considered keystone species; their tunnels are up to 40 feet (12 m) long, and more than 300 species are known to take refuge there. In the Southwest, Desert Tortoises (*Gopherus agassizii*) live in arid regions where they excavate long tunnels that are known to support more than 100 species. The extirpation of these amazing animals has also left hundreds of other species without necessary refugia, hibernating spaces, and even hunting grounds. In regions where tortoises should exist, underground burrows should be added to garden designs to create habitat for other wildlife dependent on these shelters (see the chapter 2 section "Burrows, Caves, Crevices, and Rock Shelters").

Badgers

The American Badger (*Taxidea taxus*) is an impressive and often overlooked predator and scavenger. Its diet is composed of small animals, including gophers, ground squirrels, mice, rats, rabbits, birds, lizards, toads, insects, wasp's nests, and even fish. When badgers prey on these animals, their burrows become abandoned and available for other animals to occupy. Depending on prey availability and badger populations, a badger's home range can be under a square mile (2 km^2) to more than 100 square miles (260 km^2). This range means that the solitary American Badger was never overly abundant in any landscape, but badgers still play major roles in the overall ecosystem.

Throughout their home range, American Badgers excavate burrows for a variety of purposes. Many burrows are the result of chasing prey, while some are made for resting and others are for denning. Denning burrows, especially ones used for overwintering,

An illustration of an American Badger (*Taxidea taxus*) outside a burrow. These animals have large territories with numerous burrows that are used by many other species. INSET: American Badger (*Taxidea taxus*) range map.

are deeper and have more complexity than resting burrows, but both provide escape from the elements. Most importantly, only a small proportion of the excavated burrows are actively used, which leaves most burrows free for other animals to use.

Diggers and Scrapers

Many animals, including birds, bears, bison, Elk, and armadillos, dig through leaf litter and areas of topsoil while looking for food. These actions help expose soil, disturb organic layers, and improve nutrient cycling. Some animals disturb less than a square foot at a time as they hunt. For example, American Robins (*Turdus migratorius*) and towhees (genera *Melozone* and *Pipilo*) can often be seen rummaging through leaf litter and scraping topsoil away to expose soil invertebrates. Other species disturb larger areas, such as when a badger digs up a wasp's nest or anthill, a javelina (aka peccary; family Tayassuidae) roots up areas looking for grubs, or a Pileated Woodpecker (*Dryocopus pileatus*) tears apart a log while eating ants.

Some of these species are present in urban areas; meanwhile, re-creating these disturbances can improve soil quality and hunting opportunities for wildlife. Occasionally raking areas where organic materials, like mulch or leaves, are laid out helps the material break down as well as exposing some of the soil invertebrates. Overturning soils between plants and pulling up weeds and leaving the roots facing the sky also exposes soil invertebrates for birds to prey on. Moving logs, pots, and other objects sitting on soil similarly encourages prey species to move about as well as preventing settling; this action ensures that space exists under objects that small animals like lizards and toads can squeeze into.

— Cavity Makers

Possibly one of the best-studied microhabitats that can be created by an ecosystem engineer is the wooden cavity or hollow log. Two main types of tree cavities exist: cavities caused by decay and excavated cavities. Decay cavities are produced by a

A Pileated Woodpecker (*Dryocopus pileatus*) tearing apart a fallen log to access the insects inside. Spreading woody debris around the ground and opening up the log facilitates nutrient cycles and creates microshelters for animals to take refuge in.

A Hairy Woodpecker (*Leuconotopicus villosus*) bringing food back to its nest, in a cavity it likely created. Woodpeckers open up hollow shelters that are used by many animals.

combination of wood-eating fungi, insects, water, and dry periods that break down the non-living interior of trees. Excavated cavities are made or completed by animals removing wood to create hollow spaces. Primary cavity-nesters, like woodpeckers and rodents, can excavate cavities or simply create access points leading to hollow spaces formed by decay. Formations of both cavity types are affected by climate and the regional suite of cavity-creating species.

Tree cavities are critical for a myriad of animals living both on the ground and in tree canopies. Localized density of tree cavities is known to affect local populations of various animals. Ornithologists estimate that 9% to 18% of bird species around the world depend on cavities for nesting. Similarly, various mammals, insects, amphibians, and reptiles shelter in tree cavities and hollow logs. Pools of water that collect in some cavities are important hydration resources for canopy animals and even breeding locations for various insects and frogs. Unfortunately, tree cavities are destroyed by deforestation and urbanization. Common practices in silviculture and tree maintenance near residences and businesses suppress the development and overall abundance of tree cavities. Near buildings, cavity-rich, old tree stands are regularly removed because snags and dead trees in those lots are viewed as hazardous. Likewise, old, dying, and decayed branches where cavities regularly form are removed, which subsequently affects animals that depend on tree hollows.

Fallen trees and downed branches can also hollow out over time, which provides shelter for ground-based animals. Large trunks can become denning locations for mammals, and hibernating and egg-laying sites for reptiles and amphibians, while providing shelter for numerous other species. Much like standing and hanging dead wood, downed wood tends to be removed from developed areas. In turn, nesting sites,

ABOVE LEFT: Common Raccoon (*Procyon lotor*) peeking out of its refuge in a provided shelter box. In non-urban settings, Common Raccoons regularly use hollow branches and trunks for bedding and nesting.

ABOVE RIGHT: Cavity-creating animals like woodpeckers (family Picidae) often create access to hollow branches and introduce organisms that feed on the non-living wood inside limbs and trunks. Many bird and mammal species modify openings to gain access to these spaces for nesting and shelter. Broken limbs also create habitats that can be used for shelters and even hold water.

shelters, and all of the life cycles dependent on those sites disappear from the landscape and our developed areas. Including standing and fallen wooden cavities in gardens and conservation efforts is incredibly important to provide a complete habitat.

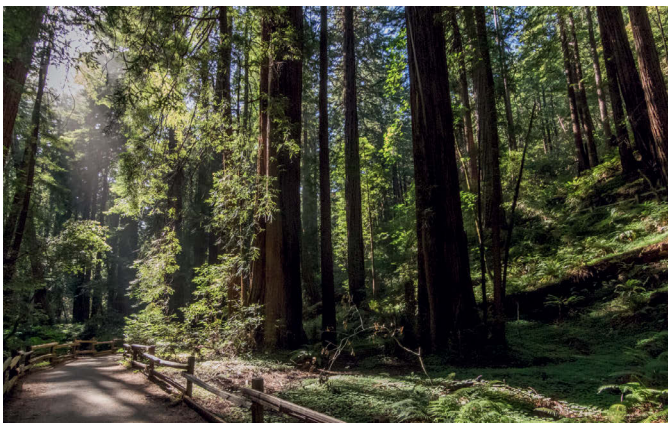
Providing resources that mimic tree cavities is common, although most folks do not recognize the connection. Hanging up bird nest boxes, wildlife shelter boxes, and even bee hotels replicate resources naturally created by tree hollows. Use of these resources by wildlife is affected by height, sun exposure, and the direction of the opening. Less commonly included in landscape designs are large, downed logs and standing snags, even though they can create stunning centerpieces. For more information on the design and placement of cavity resources, see the chapter 2 section "Wood."

— Plants as Ecosystem Engineers

Ecosystem engineers are most often considered to be animals; however, many plant species are ecosystem engineers as well. Large-canopy trees create cool, shaded

This large oak tree on Catalina Island, in California, augments local habitat by fog drip. When condensed fog collects on leaves and falls to the ground, soil moisture is increased and cooler microhabitats form.

microhabitats; deciduous trees facilitate organic material buildup and soil creation; pine trees and other plants create acidic soils; and there are even ecoregions around the Pacific Coast where trees increase soil moisture through fog drip—where moisture condenses on leaves, then falls to the ground in measurable amounts. Some tree species have canopies and branches so large they support vegetation communities. Old-growth Giant Sequoias (*Sequoiadendron giganteum*), for example, support dense soils, ferns, shrubs, and even other trees in their canopies. As trees mature, many species regularly support cavities in their living branches that provide important shelter for wildlife as well as capture water. The bark texture of tree species also facilitates the growth of certain lichens and epiphytic plants like resurrection ferns (genus *Pleopeltis*).



Giant Redwoods (*Sequoiadendron giganteum*) in Henry Cowell Park, in California. Old-growth trees are known to have large fern beds in the canopy, as well as secondary trunks and fully mature trees growing in soil masses.

A fallen tree provides microclimates for a variety of plant species that differ from the ones establishing in the surrounding area in eastern Minnesota.

There are also many plants that can cover large areas through cloning and in turn engineer local habitat. One of the largest organisms in the world is a single aspen tree in Utah; named Pando, it looks like a forest but is one tree connected by its giant root system. Various plant species, including grasses—especially some species of bamboos (subfamily Bambusoidea), milkweeds (genus *Asclepias*), goldenrods (genus *Solidago*), and wormwoods (genus *Artemisia*)—are some of the other species able to

A suburban yard supporting a mature oak (genus *Quercus*) tree that was planned out when put in the ground.

take over areas. These clonal-growth species often employ a division of labor in their resource-acquisition roles; stems have different local specializations, which enables the uptake of different resources from sites of greatest abundance.

Promoting ecosystem engineer plants in gardens can be difficult because old-growth trees take centuries to grow, and clonal herbaceous species can quickly take over a garden. However, planning for a garden to still support a single tree two centuries in the future is commendable. Luckily, there are only a few species that are dependent on the old-growth canopy for their life cycle, which means our work can benefit wildlife quickly. Most species that live in old-growth canopies either exist in similar terrestrial areas, like fern beds on the ground, or utilize the canopies of younger trees. This means

WIND

Vegetation has many roles in ecosystems, from providing food and shelter to creating structure, shade, and microclimate. Habitat structure is important because it affects microclimates, including local wind speeds, and can provide refugia when windy conditions occur. Although gusty conditions happen in all ecoregions, especially during storms, some areas like the Great Plains, the Chihuahuan Desert, and mountaintops regularly sustain long periods of blustery conditions. The landscape and plant-community structures in these areas provide spaces that are fully exposed to the full force of wind, as well as protected areas where breezes are hardly noticeable and measure below 1 mile per hour.

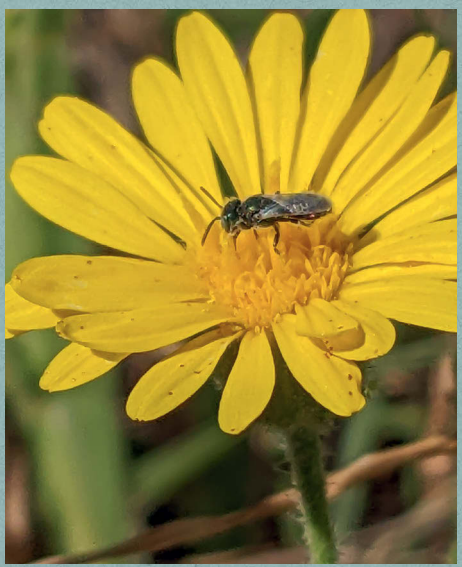
In wild habitats, windbreaks exist between plants, over trails, under leaf canopies, in depressions, and along fallen logs or stones. Such windbreaks are usually absent in mowed parks, denuded roadsides, and other managed, developed landscapes.

A managed landscape with short, mowed vegetation among trees. Areas like this have higher wind velocity compared to spaces with more vegetation structure. Managed landscapes often lack structure and windbreaks, which can make areas inhospitable for flying insects.

that caring for trees that are ecosystem engineers supports many animals and plants that can live in the old-growth canopies as well. Planning gardens with trees and adapting as those trees grow is the best way to encourage canopy-dependent wildlife. An important aspect of planning takes the final size of the tree into account. Tall trees like Coastal Redwoods (*Sequoia sempervirens*) and tulip trees (genus *Liriodendron*) should be planted far enough away from structures that they are not perceived as a threat that might crush homes. Wide-canopy trees, like oaks (genus *Quercus*), should be planted far enough away from buildings that branches won't grow over areas that would require pruning or be perceived as dangerous. Designing areas to include clonal species in gardens can be done using large pots, underground barriers, and isolated garden beds.

Preliminary data on the lack of vegetation structure in managed landscapes show wind speeds regularly exceeding bee-flight speeds at ground level. Conversely, in areas with more structure, wind speeds near the ground and within vegetation canopies stay below 10 miles per hour (16 kph), even when wind gusts are over 40 miles per hour (64 kph). Exposed, windy areas are problematic because solitary bees must fly to forage, and if their nests are experiencing high winds, they cannot reach flowers and return. From this, it can be deduced that bees will have decreased nesting success and lower survivability due to higher winds, but formal data analyses are needed.

As more land managers implement bee-friendly lawns with clover, low-growing flowers, and turfgrasses, ensuring that windbreaks are also present will enable bees to forage when wind speeds are high. Areas with houses, shrub lines, and fences tend to have more windbreaks, but open areas are common along roads and front yards. Providing topographic and vegetative structure creates more robust habitats and allows flying insects to stay active on blustery days.



A small bee (genus *Perdita*) on a low-growing flower. These bees fly close to the ground between vegetation in areas with regular high winds. In vegetation that has been cut short and roadsides with sparse vegetation, these bees and other small flying insects are absent, likely because the wind speeds are too strong.

Wildlife Populations, Life Cycles, and Natural Enemies

Species populations can be discussed in a few different ways. Sometimes, *population* refers to every single individual that exists; at other times, the term refers to a regional group or specific members in a single habitat or subset of interconnected habitats. Generally, when population cycles are discussed, the conversation focuses on a regional group or individuals living in a specific area, like a river basin or park, or around a city. For simplicity, these populations can be referred to as local populations.

Naturally, local populations experience booms and busts, which are driven by both biotic and abiotic factors. When overall habitat conditions are good, populations can boom or grow in size. Predators of these populations will follow with population growth due to the amount of food available, eventually leading to a decrease in prey populations. In many high school biology classes, this process is explained using the Canada Lynx and hare model, which is a good introduction; it describes the predator–prey relationship between the two species, particularly their population cycles in the boreal forests of North America, and shows that lynx and hare populations fluctuate in 8- to 11-year cycles. The lynx and hare model, however, does not introduce the effects of multiple stressors, such as predatory species, diseases, and parasites. It also leaves out the abiotic conditions like harsh winters, intense summers, and droughts that also influence these cycles for every species.

In healthy ecosystems, all of these factors interact in a way that causes populations to change, even disappear locally, but not go extinct (except in rare cases). Trying to

ABOVE LEFT: A blue vane trap used to collect native bees for monitoring populations. Data collected here help identify bee community structure and bee abundance.

ABOVE RIGHT: A lizard captures insect prey. Large insect populations help lizard populations grow. Poor insect abundance causes the lizard population to shrink.

conceptualize the networks of species and the stressors they place on one another is impossible when considering entire habitats. However, by understanding the basic cause and effect of these interactions, we can begin to recognize potential issues that may occur when ecosystems have species removed or processes changed. We can also consider pressures with positive and negative stress on species. For example, good weather, lots of food, and low natural-enemy populations (predators, parasitoids, and parasites) would be positive and allow a local population to grow. Similarly, bad weather, limited food, and high natural-enemy populations would negatively affect populations.

Gardens are an interesting place to apply this thought process, especially when considering insects. Monarch butterflies (*Danaus plexippus*), for example, have a naturally low survival rate due to the number of natural enemies they have. Historically, their habitats used to be much more abundant, and host plants existed in varying densities that changed every few years. This led to a balance of populations over the entire landscape. Currently, gardeners who grow milkweed create food islands for both the Monarch larvae and their natural enemies, where adult Monarchs can fly in and lay eggs, and natural enemies can feast. This can lead to higher mortality rates than occur naturally. There are a few instances where local populations were documented to have 100% mortality. Projects that this author has worked on with Monarchs have documented complete loss of caterpillars and pupae in gardens from predators and infestations of *Pteromalus cassotis* (a gregarious pupal parasitoid) in three separate states. Similar patterns were observed in the Glanville Fritillary (*Melitaea cinxia*) and are likely occurring in other insect species with mobile adults. There are also times where gardeners encourage this pattern, like with Tomato Hornworms (the caterpillar of the Five-spotted Hawkmoth, *Manduca quinquemaculata*), using natural enemy populations to reduce plant damage.

In healthy ecosystems, these localized events would be part of the normal pattern of populations moving around the landscape. Movement is caused by abiotic factors, including weather patterns, fires, floods, and cycles of vegetation-community succession. Biotic factors would also influence populations of natural enemies, like

A Tomato Hornworm (caterpillar of the Five-spotted Hawkmoth, *Manduca quinquemaculata*) with ectoparasitoids attached that will inevitably kill the caterpillar. Many gardeners encourage these wasps to control hornworm populations and remove the caterpillars when they become too abundant.

the disappearance of the populations of animals that consume the natural enemies of lepidopteran host plants. In our current landscapes, these stressors aren't all connected or even present, so it is important to take action when certain populations like predators and parasitoids are too high. Some of these actions are discussed in the chapter 2 section "Replicating Absent Predators" and the chapter 4 section "Monitoring, Responding, or Letting Nature Take Its Course."

Conclusions

Natural systems are incredibly complex, and they are changed drastically by the presence or absence of a single factor, let alone multiple variables. Due to this complexity, wildlife have evolved to persist in a range of habitats that provide key resources for their life cycles. Even under the current pressures of habitat loss, pesticides, climate change, land-management practices, pollution, removal of keystone species, and establishment of invasive species, many organisms are persisting. Although there are protected "wild" areas, including national parks, it is important to understand that not a single acre in North America is unaffected by the loss of species, removal of Native Americans from their land, and destructive human activities. Of course, some areas are less affected than others, which allows us to better understand how habitats should exist in landscapes over time. However, we must also consider the interrupted processes that play important roles, especially when visiting natural areas. We can begin to re-create better habitats for wildlife by viewing ecosystems with the understanding that large megafauna and keystone species are absent; that nutrient cycles, fire intervals, and water availability have drastically changed; and that habitat succession should be occurring. Actions that we must take include mimicking behaviors and processes extirpated animals facilitated, promoting nutrient cycles, and refreshing resources in habitats that are outside of succession patterns. This holistic approach promotes better management practices, including ways to care for habitats in gardens, natural areas, urban landscapes, and suburban neighborhoods.

An alpine trail among coniferous forests is perfect inspiration for garden design.

SMALL-SCALE URBAN CONSERVATION

A neighborhood aerial image showing nearby resources that wildlife might use. Trees, parks, and a lack of gardens and water resources are evident in the area.

Landscape Inventory and Garden Goals

Most gardeners only have control over their own property, while most wildlife are moving around with no regard to legal boundaries. Therefore, it is important to consider a garden as it relates to the surrounding landscape. For example, if, in the accompanying aerial photograph, we consider the house pictured and marked in green, we can see that the front and back areas lack trees. However, almost every neighbor has a tree or tall shrub. If the homeowner here did not consider their yard in the overall landscape, then it would seem like a great idea to plant trees to help provide nesting and shelter resources for wildlife. However, wildlife that can fly, or travel quickly, could easily use the trees in neighboring yards, so nesting resources are not a limiting factor. Looking around the area, there appears to be a lot of barren ground, cement, asphalt, buildings, rockscapes, and a lack of water and food. Therefore, a more productive use of the yard for wildlife would be to provide places for animals to drink and eat. Similarly, the nearby trees likely are taken care of and therefore won't have good cavities for nesting. Dead wood is important for various wildlife, including cavity-nesting birds and mammals, numerous insects, and even some amphibians. So, if this area was planned to help songbirds, installing shelter for cavity-nesting birds like bluebirds (genus *Sialia*) and wrens (family Troglodytidae), like nest boxes, would provide the missing deadwood resources. Planting native plants would increase insect forage for the birds to feed their young, and adding a water resource would help them hydrate.

From the photograph, we can also see that very few yards have lawns (a good indication that there is lower pesticide use), but there is also a lack of gardens. There is a large lawn area in the park to the east. Open spaces like park lawns and the additional water to maintain lawns often support a variety of wildlife, including some nesting bees, larger predatory birds like Red-tailed Hawks (*Buteo jamaicensis*), invasive species like feral pigeons (family Columbidae), and House Sparrows (*Passer domesticus*), as well as various mammals like cottontail rabbits (genus *Sylvilagus*) and ground squirrels (tribe Marmotini). Maintained open spaces are also commonly full of pesticides, which can harm all of the wildlife exposed. If there are open spaces near your home, it is beneficial to investigate those areas to see which wildlife are present and might visit and even establish in your garden.

Visible in the photograph are numerous roads and houses, which are impervious surfaces that lead to runoff and heat retention. Impervious surfaces can lead to localized flooding during rains, inhospitably hot surfaces, and host dangers associated with cars. Any shelters placed in the yard should take into account roads and sidewalks. Placement for most walking and crawling animals should be located away from the roads. Another important thing to take note of is how much water

An urban park with soccer fields and a footpath that is heavily irrigated. Irrigation provides water resources for some animals, while pesticide use and mowing make the space unusable for many species. Useful fields should be maintained, while non-field areas could be converted into useful native habitat and food plots. Petition local government when this is an issue.

is available in the landscape. In the above example, no pools or ponds can be readily observed, so water in the landscape is likely a limiting resource. Simply adding to the yard a small water feature at ground level would be a huge benefit to local wildlife. Conversely, if water was readily available, it would not be as beneficial to add for wildlife but could still be a focal point for the landowner. Judging from the photograph, the surrounding landscape is also lacking dead wood, flowers, and large, seed-producing plants that would benefit many birds, pollinators, and other species. When you identify the resources that are absent or scarce in a landscape and then provide those resources in a yard, wildlife will quickly begin to utilize the area.

Take the time to use a map service like Google Maps to look at the satellite imagery around the area where you are planning a garden. It is also a good idea to walk around and see what other gardeners have in their yards. Similarly, it is helpful to observe plants and animals in areas that are not maintained because they may be easy to attract by providing their absent resources. Make sure to take note of the resources you can see in the landscape. Is there standing water? Are tall trees present? Unmaintained areas that could be good for wildflowers or bees and butterflies? Once you have an idea of the resources around your project that wildlife may be using and the resources that are absent or limited, you can start to narrow down the resources to add to your garden to attract target wildlife. Keep in mind that non-flying animals have to be present in the nearby landscape for them to establish in a garden.

Asphalt and dry landscaped areas are common in cities and developed areas. Smarter planning can create habitat for wildlife that provides drought-resistant plantings, along with rockwork, shelters, and small hydration stations. Working with local governments and businesses can help improve these spaces for wildlife.

Where to Start

Redesigning an area can be overwhelming. As with any big project, it is important to break things down into steps. My recommendation is to try to make each step take only a few hours to a single weekend. Consider hiring a professional if it will take more than a weekend. Folks reading this book likely have yards ranging from large lawn areas to well-established, native-plant gardens. Read through the steps and start off at the point that works best for your yard.

— **Step 1:** Choose a garden design type

The first step in creating a native habitat is to choose a landscape aesthetic that you like and that meets any applicable ordinances. Native plants have quite a few potential critical issues, one of which stems from gardeners trying to create areas with native plants while ignoring the structural aesthetics, clean borders, and organization that many people and cities expect to see around our homes. To further confuse the topic, many people conflate the "use of native plants" with "wild landscapes" that are not weeded, trimmed, or managed. Even though native plants are a major part of wild landscapes, they can be used to design organized, purposefully planted landscapes. It is simply a matter of choosing the right plants and sometimes having patience. Likewise, our neighborhoods lack many of the herbivores and natural processes discussed in chapter 1 that make vegetation communities into habitat for

A lawn-to-prairie project in Bedford Hills, New York. The owners had stopped mowing three years earlier in hopes a meadow would form. Mostly invasive plants and some native shrubs grew instead.

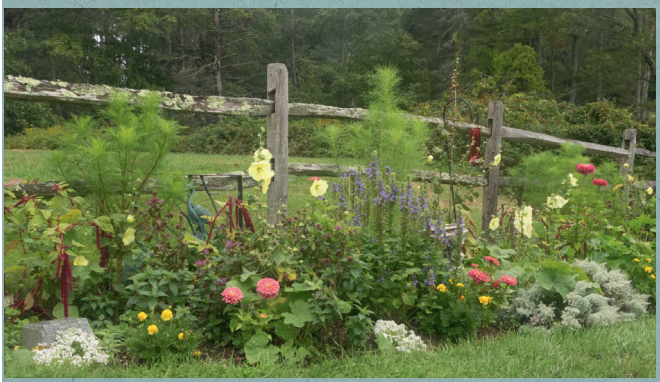
so many species. Simply seeding or placing native plants into an area and allowing them to grow freely provides habitat for only a few species. There is also the issue of city and neighborhood ordinances that dictate acceptable yard aesthetics with the ability to fine homeowners for areas that appear unkept or are deemed safety hazards.

Luckily, most ecoregions have plant species that tolerate heavy pruning or have growth patterns that make them great substitutes for traditional garden designs. This means that any traditional or non-traditional garden type has an equivalent that can be created using native plants. English hedge mazes and topiary gardens can be planned with native plants using species that are heavily browsed and that tolerate shaping. Ecoregions also have plant species that naturally grow close to the ground or mound that work great in borders. However, finding particular species at nurseries can be extremely difficult, especially in more rural areas. When this is the case, collecting seeds or propagating plants from cuttings is necessary. Maintaining the garden with pruning, weeding, and care mimics natural processes that create new resources for wildlife and can keep the target aesthetic of the landscape.

Some people are fond of formal gardens like English hedge mazes, topiary gardens, and Japanese gardens, all of which are filled with trimmed plants and clean lines. If this is the style you like, there are shrubs across the continent that tolerate the heavy pruning necessary to create a topiary. Many of the native plants that tolerate this are heavily browsed by herbivores. Some top choices include native junipers like Eastern Redcedar (*Juniperus virginiana*), Texas Sage (*Leucophylum frutescens*), Yaupon Holly (*Ilex vomitoria*), various plum species (genus *Prunus*), Running Serviceberry (*Amelanchier stolonifera*), and many shrubs in the *Ceanothus* genus, just to name a few. Statue-like topiaries can also be made using plant substrates, mesh, and appropriate natives, including succulents, vines, and epiphytes; however, not all ecoregions have plants that tolerate these growing conditions.

Less-formal garden types that require annual pruning and periodic weeding include cottage gardens, Mediterranean gardens, woodland-edge gardens, and other nature-inspired designs. These gardens focus more on layering planted areas, organization of the landscape, color, and the incorporation of natural features, including ponds, fallen trees, and dry streambeds. For gardeners who enjoy the wild-meadow look, planter beds with clear borders, including long, narrow beds, can be incorporated into the design. Each planting area can then be filled with native wildflowers and plants, even allowing some beds to have wildscapes that contrast against organized borders and paths. For nature-inspired gardens, take the time to peruse picturesque landscapes of the ecoregion you live in for design inspiration. With a little planning and patience, you can create beautiful gardens that are incredible wildlife habitat, filled with native plants and non-floral resources that adhere to local ordinances.

LANDSCAPE OPTIONS

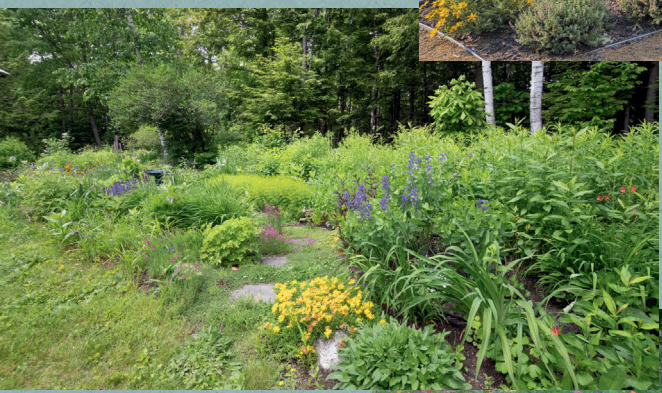


A cottage-garden-style bed along a fence line.

A formal garden with a pergola and large beds filled with natives.

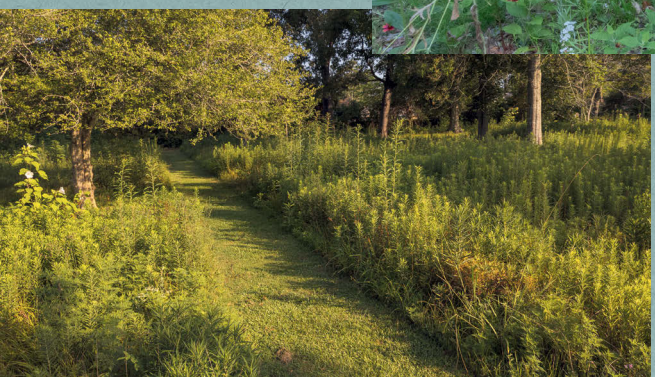
A Japanese garden in Missouri.

A nature-inspired garden design with clear borders, layering, and rockwork.



LEFT: A natives-dominated garden design with clear borders, paths, and organization that should not violate weed-ordinance laws.

RIGHT: Although many colorful flowers grow in this wild garden, the lack of organization, borders, and design could lead to weed-ordinance violations.



A mowed path through a native pollinator meadow dominated by nectar-producing plants.

A garden bed with hedges and equally spaced shrubs that tolerate trimming.

A modern native-plant garden that requires some regular weeding and annual pruning.

No matter which design type you chose, areas designed with native plants should have clear borders, especially near sidewalks, driveways, and other publicly visible areas. Borders can have low-growing plants, low rock cover, pruned shrubs, orderly groupings of plants, and/or equally spaced, eye-catching plants like cactus, yuccas, bunchgrasses, and compact shrubs. Try to reduce the use of weed liners because they prevent soil-nesting insects from using the area and need to be replaced every five to eight years. If your design uses weed liners, try to only place them where absolutely necessary. Large, flat rocks are great natural weed blocks and can be used to create shelter for wildlife like pupating moths, sleeping amphibians, and many other small animals escaping the elements.

An unplanted garden clearly illustrates that shelter is often lacking in landscape designs. Once planted, this area could be suitable to host a few developing caterpillars, flowers to feed pollinators, and enough plants for some herbivorous insects. Conversely, it is too small to comfortably support resources for the life cycle of most amphibians. This space could also be drastically improved for insects and pollinators by adding in non-floral resources, nesting soils, mulch, and logs for invertebrates to carry out all stages of their life cycles.

— **Step 2:** Select a few target wildlife species to promote in the garden

As you are designing your garden, the design must include the habitat requirement of the target wildlife species you want to attract. This includes food and specific elements each species utilizes in the wild and the need for access points. For example, toads need areas to soak, but a birdbath on a pedestal is inaccessible and does not function as a water resource for them. Likewise, the size of the garden will heavily influence which species can safely reside in or utilize the landscape. Smaller gardens are great for insects and animals that are already present in the nearby landscape. However, small gardens likely will not attract or be able to support larger animals that have been extirpated from the area. Furthermore, there is an overarching problem in urban environments—the removal of resources for wildlife, especially shelter and food. In current landscapes, areas where animals shelter or nest are generally added to the landscape without wildlife in mind. These spaces include rockscapes, cement slabs, pots, garden hoses, and other objects. Quite often, animals sheltering in unintended areas are accidentally disturbed by gardeners, putting wildlife at

A hummingbird (family Trochilidae) nectars on a dome flower (genus *Gaillardia*). Planting nectar-rich flowers will attract a wide variety of animals.

higher mortality risk from exposure and predators. Fortunately, many resources can be intentionally provided, beautifully built, and easily integrated into a wildlife garden that can attract animals to safer locations. These ideas are discussed later in this chapter in various sections, especially "Wood" and "Burrows, Caves, Crevices, and Rocky Shelters."

Urban areas also add features, pollution, and risks to the landscape that wildlife have to contend with. Many common urban-wildlife species benefit from the addition of water and trees, and some species even do well finding shelter. However, water and soil are often polluted with salts and oil from roads, as well as pesticides and fertilizers from homes and greenways that can make wildlife sick. Direct interactions with vehicles are dangerous for most species, and they increase with the increasing density of roads. Indirect interactions include being affected by the noise, air, and

A male skink (family Scincidae) hiding in the crack and washout of a rock wall in Tulsa, Oklahoma. Although this area was not intended for wildlife, the space is sufficient for this lizard to take refuge. Unfortunately, the space is right next to high-traffic, public footpaths, exposing the skink to risks of being squished or captured.

Rockscapes with intentional crevices for a more natural and wildlife-friendly design. Even with the intention to provide shelter, the gardeners overlooked key soil characteristics, like exposed clay or pockets of sand, that benefit different wildlife.

light pollution that vehicles create. All of these factors can impact breeding and daily behavior. For example, research studies have found that urban birds sing louder than their counterparts in more wild settings, likely in order to be heard above the noise pollution. Predatory insects, like ground beetles, are more abundant at streetlights, while research has also shown that insect diversity drastically decreases in these same illuminated areas. This might be because plants growing under artificial lighting in developed areas have been found to be inedible by insects.

When a water-retention pond is filled by runoff from a gas station, the result is a heavily polluted water resource unsuitable for most animals to drink or breed in.

A side-blotched lizard (genus *Uta*) sits on concrete rubble to sun itself. Providing rocks and shelters for lizards to sun on is further discussed in chapter 2 section "Burrows, Caves, Crevices, and Rocky Shelters."

Making sure your area is kept clear of chemical pollutants, while reducing as much noise, light pollution, and exposure to traffic as you can, will make your garden the most wildlife friendly it can be. This means that noisy machinery and yard decorations like generators, HVAC units, and wind chimes should be grouped together. Landscape lighting should be limited to key areas for safety and, when possible, turned off. Motion-activated lights are the best option, with timers and manual lights a close second. More and more data show that artificial lights affect insect abundance, attract predatory beetles, and make plants unpalatable for many lepidopteran larvae. The one exception is light fixtures intended to attract food for nocturnal predatory animals, like toads, frogs, and some lizards, which should be pointed at the ground. Features like feeding stations, watering areas, and shelters should be placed away from roads to avoid vehicle interactions and contaminated soils.

Chapter 3 of this book contains profiles of a variety of wildlife species, including important habitat requirements for each species. Use those profiles as a framework for necessary details to consider when creating habitat. Consider these critical life-history components for each species: where precisely it overwinters, where eggs/young are placed, microhabitats for nesting and active-season shelters, water use/access, and the ability to move around the designed landscape in all life stages. Utilize any resources you can find on the species you want to promote to further guide your garden design so that you can provide both floral and non-floral resources for your target wildlife species.

— **Step 3:** Sketch out planting areas/paths/features

Start planning where paths, beds, trees, and shrubs will go. Drawing up designs will help in selecting areas that can be further enhanced with shelters for target wildlife.

A project in process. Some stones are placed on the left, while areas on the right are outlined. Often, materials will inspire changes to designs. Take the time to place objects before installing them permanently.

It is also helpful to mark paths and beds to visualize the end goal. Make sure to note sun exposure, water and moisture, and other abiotic factors that could affect plant success and wildlife. Modify the plan as necessary until a design is finalized that creates robust habitat and gorgeous views, while simultaneoulsy abiding by all ordinances.

— **Step 4:** Choose plants based on target wildlife, and select spaces to install non-floral resources

When choosing plants for your garden, keep in mind that there are vigorous (aka "weedy") native flowers in every region. Roadsides and wild lots are great places to find these species, especially ones that tolerate sporadic mowing and pruning. Spreading seeds of the weedy flowers that are native to your area can create dramatic color bursts, reduce watering, and help control unwanted, non-native plants. However, these species will also grow in areas that are intended for other plants, so weeding is necessary. Keeping species grouped together in separate planting areas

Local groups often have native plant sales that provide local species not commercially available.

A native landscape in Shasta, California, using aesthetic guidelines with layering, color, and texture.

and simply keeping them trimmed back will help onlookers understand that the area is intentionally kept, which should stop most complaints about gardens based on natural landscapes. Another reason to add weedy species is that many support butterfly caterpillars and many adult pollinators, while surviving local weather extremes.

Perennial forbs, grasses, shrubs, and trees should be selected to build layers and structure in the garden as well as feed native wildlife. Insects that benefit from the chosen plants should be evaluated to ensure that all resources for their life cycles are met in the landscape and nearby areas. This may require modifications to the landscape design, but it will be worth it when the garden fills with wildlife. Likewise, pollinator-friendly plantings attract a variety of insects and birds. Selecting a variety of plants to provide flowers throughout the growing season promotes visitation from pollinators and overall wildlife activity throughout the warmer months.

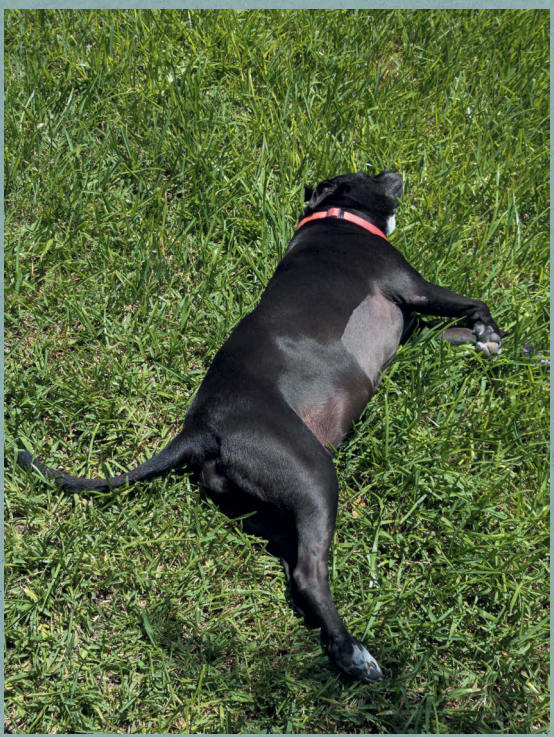
— **Step 5:** Begin installation

Prior to digging, make sure to call the proper utilities to have their lines marked. Start small by either selecting a single garden bed to install or by planting larger plants like trees and shrubs. Break down each project to tasks that can be completed in less than two days, which will prevent you from being overwhelmed.

Shovels and tools laid out to begin a large conservation task of removing the grasses and installing native plants in a fenced-off area. This garden was used for the propagation of plants to be used in conservation projects around Westchester County, New York.

LAWNS

Although traditional lawns are generally environmentally unfriendly due to chemical applications, herbicide use, water demand, and constant mowing, they do have their appeal and functional use. Lawns are great for providing space for kids and pets to run and play; they make good, soft workspaces; and they are well suited for paths and borders. If having a lawn is important for your household, HOA, or even city ordinances, it is imperative to change the methods by which the lawn is maintained. To make lawns more wildlife friendly, the most important change is to stop using pesticides and use natural fertilizing methods. Pesticides include fungicides, herbicides, and insecticides. Research shows fungicides have terrible effects on insect populations, possibly worse than insecticides, because they both kill insects and make them susceptible to contracting and spreading diseases. Avoid using insecticides, especially long-lasting varieties and broad-spectrum chemicals. At this time, there are no spray insecticides that are safe for bees, no matter how the company advertises it. However, there are ways to use insecticides to reduce harm to non-target insects.



Lawns have their uses as areas for play, soft work spaces, and pet use. In many instances, lawns are required by ordinances. Where possible, lawns should be removed, but if lawns are used regularly, they are a better alternative than cement.

Application can be reduced to areas used mostly by the unwanted species, like crawl spaces, and areas where target species are not welcome, like around patios and house entrances. Localized traps, like ant stakes and cockroach traps, can help take out some species while keeping collateral damage down. Lastly, glue traps are terrible for wildlife and are not an appropriate tool to use—ever. Glue traps kill more beneficial wildlife that eat the "pest" species and simply lead to more pests because the predators are extirpated. For more information, contact your local wildlife outreach offices (government or university) for best practices in your area.

Other important steps for maintaining a wildlife-friendly lawn are to allow non-grass plants like clovers (genus *Trifolium*), lawn asters or wild asters (genus *Symphyotrichum*), ponysfoot (genus *Dichondra*), violets (genus *Viola*), and even dandelions (genus *Taraxacum*) to grow. When possible, use native grasses like Buffalo Grass (*Bouteloua dactyloides*), St. Augustine Grass (*Stenotaphrum secundatum*), and sedges (family Cyperaceae) for lawns. If weeds show up that produce spiny vegetation or seeds, you can use manual methods or targeted herbicide application to remove them. Replace "weed 'n' feed" granules with fresh compost (spread lightly), or use nutrient teas to fertilize the area. Using a 3-inch (7.5-cm) blade height (or taller) on mowers helps reduce water needs and allows more plant diversity. For more details on best mowing practices, see the "Mowing" section later in this chapter.

A White-crowned Sparrow (*Zonotrichia leucophrys*) pecks around a mowed area with turf grasses, dandelions, and other species that tolerate regular, low trimming. This is a more environmentally friendly area than a pesticide-treated lawn.

Creating Soil Profiles for Plants and Animals

In the past four centuries, human actions have heavily disturbed and modified soils, reducing the diversity of soils in local landscapes. Over the past century, heavy machinery has substantially increased the extent of disturbance and homogenization of soils in both agricultural lands and developed spaces. In urban and suburban areas, large construction projects, like housing tracts and retail development, bring in nutrient-poor, dense soils for stability. During construction, heavy machines homogenize the soils and greatly reduce the elevation changes, fill in caves, and compact the soils. In some situations, restoring soils to a natural, plant-supporting state requires more heavy machinery to loosen the compaction and move soils. Although it is impossible to completely re-create the soil diversity that naturally occurs in an area, it is fairly simple to integrate nutrient gradients, soil-texture diversity, and topography into projects.

Over human history, methods that have been developed to reintroduce nutrients, and amend and soften soils, have generally aimed to promote crops. Some of these methods—like spreading mulch, tilling compacted soils, planting deep-rooted cover crops, and adding manure—can be used to promote healthy soils that support native plants. Keep in mind that most gardening forums and teachers focus on creating soils that promote food plants or horticultural plants, frequently referring to those soils as good and other soils as bad. Soils that naturally occur in areas, however, do not necessarily support many plants, but they are critical for wildlife. For example, compacted, sandy, clay soils stunt most plant growth, but they are sought after by a few species of

Large machinery and disturbed soils at a construction site prior to a large build. New soils, gravel, and rock are brought in to help stabilize the roads and foundation, drastically altering the space and the original, native soils.

ground-nesting, solitary bees. This means that, for a variety of situations and habitats, rebuilding native soils involves actions that won't support agricultural plants but will facilitate use by wildlife and specific native plants. Likewise, some approaches are ecoregion and habitat specific.

Before modifying soils, it is important to learn about the existing soils and what the natural soils of the area once were. There are a few options for learning about which soil types naturally occur in an area. The United States Department of Agriculture and Natural Resources Conservation Service have created the Web Soil Survey. This tool only covers the United States but includes an interactive map, drop-down menus, and links to soil descriptions. Similar data are frequently available through some local government agencies, such as state extension offices, agricultural groups, and city offices. Learning about the soils naturally occurring in an area is a good starting point, but keep in mind that these descriptions do not include small, nuanced soil types that wildlife typically require. For example, the soil descriptions explain the landform, water retention, the presence of calcium, and overall topography, among many other characteristics, but they do not include the percentage of sand, clay, and silt. On a more localized view, the descriptions also do not explain things like frequency of decaying tree trunks, nutrients, compactness of soils, and localized texture.

Soil-nutrient levels can be estimated based on current plant growth. Areas where herbaceous plants grow readily likely have decent nutrient levels that can be replenished every few years by adding chemical-free mulch or manure. It is not recommended to use chemical fertilizers for most native plants because they are intended for horticultural and agriculturally selected plants. However, if necessary, apply at one-quarter the recommended dosage to increase nutrient availability, which reduces

Undisturbed grasslands in North Dakota. Less than 1% of these grasslands are left, mostly due to row-crop agriculture.

the potential for weedy non-natives to benefit. Areas where plants are stunted, however, could be caused by nutrient deficiencies, compaction, moisture content, or texture. Look closely at areas where plants are stunted or absent. Some problems, like compaction and too much water, are easily identified. If the soil is compacted, tilling the top 12 to 18 inches (30–45 cm) will increase soil porosity and aeration. However, if the soil is simply too dense, adding sand, silt, and some organic matter will be necessary. Adding organic matter includes seeding deep-rooted plants, like tall, native bunchgrasses, and non-aggressive horticultural plants, like Daikon Radish (*Raphanus sativus* var. *longipinnatus*). Leaf mulch, sterile straw, and wood chips will also work. Use the information in the "Soil Texture" section below to identify if the soils are clay rich. If the area is holding too much water, loosening soils or adding a drain can help, but a better option would be to design around the area and keep it as a seasonal wetland.

ORGANIC MATERIAL SOIL AMENDMENTS

Heavily augmented soils in urban and agricultural areas typically have little of the organic materials that would naturally be present. Organic materials are important for feeding soil organisms, especially fungi, that facilitate nutrient cycles and improve plant health. Incorporating organic material in the topsoil so that it comprises 5% to 7% of the soil improves soil aeration, water porosity, and nutrient release. When soils are nutrient poor, inoculating the soil with soil organisms can improve plant health. Spreading locally sourced manure, mulch, or compost prior to soil tilling is generally sufficient. Studies show that adding small areas of native soil to restoration increases native-seed germination success and helps suppress invasive plant species. Transplanting potted native plants grown locally may have a similar effect.

Leaf litter feeds nutrient cycles in and around forested habitats and is integrated into the soil, most often by invertebrates.

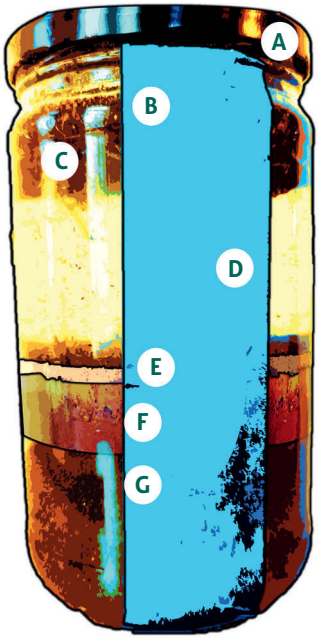
Soil Texture

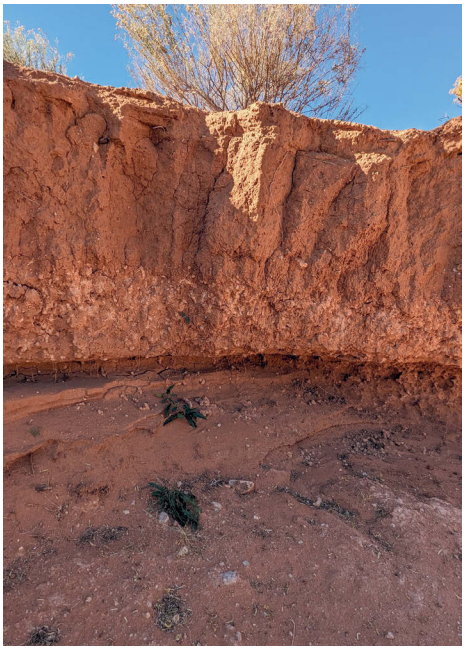
Texture is fairly simple to categorize. The most accurate way to test soil texture requires a clear, watertight container with a flat bottom and vertical walls at least 6 inches (15 cm) tall, soil, water, pen/tape, ruler, and a clock. Most instructions say to collect soil from many places in the yard and mix them together. Mixing the soils together provides a general overview of the local soil texture that can be helpful for creating seed mixes. However, for planting and planning wildlife habitat, it is important to only use soil from each test site so that the different soil types in an area can be identified.

Clay soil, with grains less than 0.002 mm long, is made of the finest grains compared to sand and silt. Clay feels very sticky when wet and can be pressed between two fingers to create "ribbons" or wide, flat structures that do not fall apart immediately. Clay holds more total water than sand or silt. This higher water-retention capability causes clay soils to swell when wet and shrink when dry. In the winter, clay soils tend to retain water, which also causes them to stay cooler than other soils in the spring because water heats up more slowly than mineral matter. *Sand* refers to materials with coarse grains ranging from 0.05 mm to 2.0 mm. Sandy soils, often called "light soils," do not retain water for long as they drain quickly. Due to the quick drainage, sandy soils dry out rapidly and are low in plant nutrients, which makes them generally acidic. Wet sandy soils crumble when pressed together. *Silt soils* have intermediate-size grains that measure between 0.002 mm and 0.05 mm, contain decent nutrient levels, are typically well drained but can become compacted easily, and hold more moisture than sandy soils. When wet, these soils hold together when pinched and make short ribbons, generally with many cracks.

For most urban settings, three or four samples will likely be enough to capture all the main soil types. However, more soil types may exist, depending on your yard. In my experience, the four main areas in urban lots that have different soils are: near the foundation, in garden beds and lawns, under large trees, and along fence lines. Be aware that new tracts of homes built after 1990 can have drastically altered soils compared to the native soils that should exist. This is due to home builders bringing in sand and fill, much of which is nutrient poor. Nutrient-poor soils can drastically affect plant survival and will not be identified in this soil test. Take the time to survey all of your property, not just where you want to grow plants. Look at the areas described above, but also in spaces that have been disturbed for paths, sidewalks, driveways, and retaining walls. Make sure to note surface texture, soil color, moisture, and even plant cover. Many areas will likely be similar, so only one of those areas needs to be sampled, but if you are curious, feel free to sample them all.

Once you have identified the different soil areas, set up the containers you will use, one for each area. Remove any organic layers, like mulch and living plants. Dig a hole



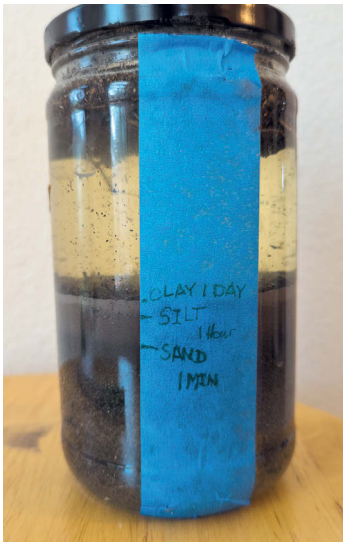


ABOVE LEFT: An illustration of the soil test to identify the amounts of clay, silt, and sand that exist in a sample. (A) Tight-sealing lid so that dirt and water can be shaken vigorously. (B) Tape to help mark and see lines for measure. (C) Organic layer that floats to the surface. (D) Water column. (E) Clay layer measured after 24 hours. (F) Silt layer measured after one hour. (G) Sand layer, which is measured one minute after agitation. The clay, silt, and sand layers are then measured to figure out the percentage each material contributes to the soil sample.

ABOVE RIGHT: Sandy desert soils sit on top of bedrock in a stream cut.

9 to 12 inches (23–30 cm) deep, making sure to pile the soil on a bare spot where it can easily be gathered. If the soil has different colors or textures between the surface and the bottom, make sure to either mix the excavated soil or take your sample from the entire wall of the hole. Fill the container two-thirds to three-quarters (66%–75%) with the soil from the hole. Make sure to label the container if you have more soil areas to test. Repeat these steps for each soil area.

Fill each container with water, leaving a little space for an air bubble to help agitate the soil, then seal tight. Clearly mark the side of the container. Some pens work well on glass and plastic, but they can be hard to see. For ease of viewing, place a thin strip of tape running up the side of the jar, bottom to top. Then use a pen to mark layers on the tape. Shake the sealed container until the soil is broken down as much as possible, then set it down where it won't be disturbed. After one minute,



ABOVE LEFT: An aggregation of soil-nesting bees in northern Mexico. Many insects seek out specific soil types for nesting , but urban soil disturbances often remove the soils needed.

ABOVE RIGHT: A photo of a completed soil test after 24 hours. For clay-rich soils, fill the jar only half full with soil for best results.

mark the side of the container at the top of the settled soil layer. Mark the settled soil layer again after an hour, and once more after 24 hours. Organic material will form a floating layer at the water surface. Mark the bottom and top of that layer as well.

The bottom layer that formed is the sand content; above that is the silt content, and then the clay content is on top. Measure the thickness of each layer to the nearest millimeter. Add the sand, silt, and clay layers together to get the sum, but do not include the organic layer. Divide each layer by the sum and multiply by a hundred to get the composition percentage for each layer. The sand, silt, and clay percentages can be used on the soil diagram to identify the type of soil at each soil area, like this:

Sand _____ **Silt** _____ **Clay** _____ **Sum**_____

Sand/Sum _____% Silt/Sum_____% Clay/Sum_____%

Organic material should be halved (divided by two) before dividing by the sum. This helps correct for the space occupied by water and air. Although organic content is not

included in the ternary soil diagram, soils with too much organic content (6% or higher) can be bad for plants but are great for fungi and overwintering animals. Many animals seek out underground wood, like large roots and tree trunks, for their nesting sites and overwintering shelters (see the "Wood" and "Mulch Piles" sections below for more).

Wood

Although living wood can be abundant in urban areas, dead wood and wooden structures that wildlife can take refuge in are typically removed. Many gardeners and conservation areas place birdhouses and wildlife shelters in landscapes to help local wildlife. Shelter boxes are incredibly important in areas where sick and old wood is removed, but these only replicate a small role that wood plays in habitats. Dead wood includes large, fallen logs, old root systems, hollow branches in the canopy, and small twigs both on trees and spread across the ground. With a little effort, many different types of wood can be integrated into garden landscapes to support wildlife.

Insects that feed or depend on dead or decaying wood at some point in their life cycle are called saproxylic. These insects help break down wood, create nesting tunnels for various native bees and wasps, and are foraged on by many animals, including woodpeckers and bears. Large logs and branches provide the most resources, as long as they have not been chemically treated. Old trunks, branches, and cut logs can be integrated into landscapes, positioned either vertically or lying on the ground. You can incorporate large, dried wood into a landscape design by using pieces as a focal point of a garden bed, hiding them behind tall forbs, and using them as border material. When logs or branches are laid on the ground, amending the soils beneath to provide loose areas for animals to excavate and small crevices for animals to scurry into provides more microhabitats than simply setting them on the ground.

Old tree root crowns, large hollow logs, and gnarled branches can be aesthetically stunning centerpieces that add unique flare to any garden, but moving them can be expensive and difficult. If you are lucky enough to live in an area with tall trees, it

A shelter box hung on a tree in a city park in Alabama. Often, folks realize nesting resources for birds are limited but fail to connect the absence of snags and standing wood hollows with the absence of birds.

A puffball (family Lycoperdaceae) emerges from decaying wood, indicating breakdown of the material and continuing the nutrient cycle.

is sometimes possible to get root structures from tree-trimming companies, local lumberyards, and even neighbors after a windstorm. In wild landscapes, fallen trees with exposed root systems create habitat for many animals. In the Northeast, it is common to find the nest of an Ovenbird (*Seiurus aurocapilla*) in vertical root crowns, while in the mountain ranges of the arid Southwest, various rodents build nests in these same spaces.

Freshly fallen trees also have soil attached to the roots that can be removed with power washers, shovels, and spray nozzles. If you are able to find one, make sure that it is legally harvested (i.e., taken from private land with consent or removed from public lands without collection restrictions) and carefully placed. Smaller pieces of wood that are easier to move can be used for borders, pedestals, and posts on which to secure wildlife shelters. In areas where wood-boring and wood-nesting insects are being encouraged, some of the selected wood pieces should be more than 6 inches (15 cm) in diameter and 9 inches (23 cm) long. Wood from trees with thick bark is important for pupating butterflies, moths, and overwintering bees that use the space between the sluffing bark and wooden center.

An old, uprooted oak (genus *Quercus*) stands in a savannah, providing vertical structure, nesting resources for xylophilous insects, and microshelters below.

Slow-compost piles are not the same as a compost bin. Compost bins turn organic waste into soil quickly and require regular wetting and turning. The purpose of slow-compost piles is to allow organic material—leaves, dead plants, twigs, branches, and even soil—to decompose at a similar rate to natural processes, without much disturbance. Piles can be small or large, tucked away under shrubs and trees and behind stones; they can even be buried in excavated pits. It is important to not disturb these piles by turning them, but material can be added at any time. Supplemental watering in dry periods can help keep hibernating animals healthy. By adding these piles to your yard, you are encouraging a natural nutrient cycle that involves many different organisms. As fungus, bacteria, and arthropods break down the organic material, nutrients become available for other species to use. The decomposition can also create warmer soil pockets in which animals can hibernate and pupate. In the wild, these piles occur from windblown leaves, wash piles from rainstorms, underground plant material breaking down, fallen trees, and leaf drop in the fall from deciduous plants.

Slow-compost piles are simple to make, and they can easily blend into the landscape with a little planning. When planning gardens, identify a few target areas (e.g., near a large rock or dense shrub that will be put in) where piles can be hidden or blended into the landscape. For areas near large rocks, add more space for the pile by digging down 6 to 12 inches (15–30 cm). For areas near shrubs, nearby soils can be removed a few inches or deeper if that will not harm nearby plants. Prepare the area where the compost pile will be placed by loosening the top few inches of soil. This will help any animal that needs to bury itself—like toads (families Bufonidae, Scaphiopodidae), the caterpillars of sphinx moths (family Sphingidae), and hibernating bumblebee (genus *Bombus*) queens—to feel safe, as well as provide shelter for worms and other invertebrates. As weeding, pruning, leaf cleanup, and other maintenance occurs, place plant materials in the pile. It is acceptable to compact piles. Placing rocks or logs on top to prevent the pile from blowing away may be necessary. Stop adding materials when you think the piles will be noticeable or unattractive.

A stump in late stage breakdown hosts crevices and microhabitats that support mosses, fungi, and insect larvae. Slow-compost piles aim to quickly mimic this process that can take decades naturally.

Leaf piles and old trunks are natural slow-compost piles. The same materials can be hidden behind shrubs, stones, and logs in garden landscapes to provide homes for insects and overwintering sites for other wildlife.

You can also water these piles once a month to help hydrate any organisms living in the piles, but it is not necessary.

If you want to clear the piles or start new ones, it is best to remove old piles in late summer/early fall after a rain event. No animals should be hibernating in the pile at that time, and any wildlife that is hiding out there will be able to find new shelter. If you are trying to increase insect diversity in your yard, make sure to check for moth and beetle pupae; place them in shaded soil and cover them slightly so they can easily emerge.

— Mulch Piles

Mulch is great for placing around shrubs and trees to help retain moisture. Thick layers of mulch also create areas for many vertebrates, like frogs, toads, and turtles, to hibernate and nest. Many gardeners in the eastern half of North America are shocked when they dig into older mulch piles and find turtle nests, which can be difficult to work around. Installing a mulch pile that you intentionally leave alone creates a safe area for hibernating and nesting animals and keeps plant materials on your property. Much like compost piles, mulch piles can be easily incorporated into garden layouts by placing them in pits or allowing vines and shrubs to grow over them.

A natural mulch pile caused by the breakdown of a tree stump. When mulch piles are created in gardens, they are often used by the same species that use late-stage decaying wood in nature.

RETHINKING DOWNED TREES

After storms, one of the first actions people do is remove toppled trees and downed limbs. Although clearing roadways, paths, and any dangerously situated debris is necessary, the debris that poses no danger or obstacle can be worked back into the landscape. Keeping downed branches and trees in the landscape allows natural processes to occur, creating more habitat for wildlife. Below are just a few examples of how to incorporate fallen trees into urban landscapes.

Uprooted Root Crown

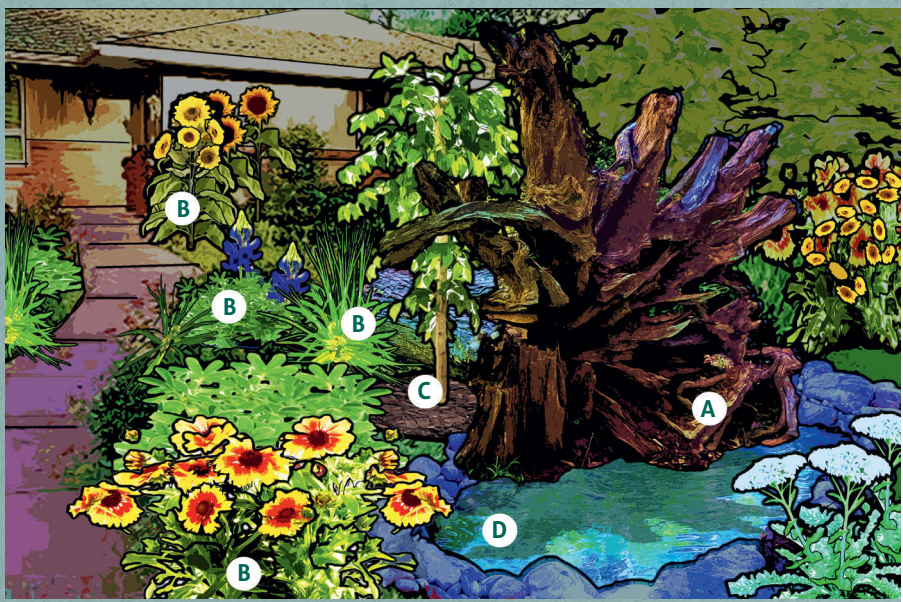
In nature, when trees fall over, microhabitats are created—both immediately and over time. As soon as the tree topples, nutrient-poor soils are exposed, vertical structures with rocks, dirt, and wood appear, and a micro-divot is left in the ground. These areas can become home to a variety of plant species and wildlife, like ferns, vines, spiders, and birds.

In most urban situations, fallen trees are removed because they are seen as "hazards," "dead," and "eyesores." Luckily, folks are realizing the importance and beauty of the fallen trees that are left in place. If attitudes can continue to shift—that is, if uprooted trees are seen as "beautiful" and "alive," with the potential to be turned into stunning structures and habitat—urban areas can begin to reintroduce the important natural cycles that occur around uprooted trees.

To turn a tree that you are taking down into an attractive piece of the landscape, ask the tree company to keep the roots standing. If this is a task you want to do yourself, first brace the root crown to stop it from falling back to the ground, then clip the roots near the soil so the tree doesn't get pulled back into place. Leaving the soil around the roots is one option, but keep in mind that the soil will eventually fall off with rain and dry

A city park in Oklahoma mows around uprooted trees. These create artistic pieces for visitors and habitat for urban wildlife.

A cleaned root crown placed in a soon-to-be-planted garden bed in Tulsa, Oklahoma. Many parks districts are adopting practices that keep organic materials in the landscape instead of removing them. Using toppled trees for structure and aesthetics is a growing trend.



A mock-up of a backyard after a tree has fallen. Instead of removing the large root mass and trunk (A), the design leaves it in place, adds sun-loving annuals and perennials to the landscape (B), replaces the lost tree nearby (C), and increases the depth of the pit with stones to create a pond (D).

continued overleaf

RETHINKING DOWNED TREES *continued*

periods. Washing off the soil as much as possible to expose the wood will create a more intentional look, and the roots will still be used by many wildlife species. Some soil that is left behind will naturally wash away or possibly fill with moss and ferns, depending on the ecoregion. If necessary, the root crown can be moved to a more favorable location. However, if it is left in place, the excavated area can be turned into a pond or refilled with dirt and planted.

In a recently prepared garden in Oregon, a White Birch (*Betula papyrifera*) needed removal. Instead of removing the entire structure, 5 feet (1.5 m) of the trunk was left standing to provide habitat for birds and insects. At this height, the structure poses much less risk to people and no risk to nearby structures. In the surrounding areas, plants that were growing in the shade may be full sun tolerant, but may also perish from the change in lighting. Establishing new garden beds allows full-sun tolerant plants to be added, livening up the area and indicating that the stump is intentionally there. A mock-up of the simple garden that was planned adds just two flowering species for a stunning burst of color and food for pollinators.

Areas on your property where trimmed organic material can be placed can also function as mulch piles, while allowing insects nesting and living in those plants to complete their life cycle. Over time, more and more organic material will be added, creating layers of microhabitats that will be utilized by animals for sheltering and foraging. In smaller yards, these piles can be spread out into multiple little piles that can be hidden behind and beneath plants and rocks and tucked behind borders of raised beds.

— Log Borders, Pedestals, and Wildlife Refugia

Small to large logs from downed trees can be turned into sheltering habitat that can simultaneously function as borders for paths and garden beds. Borders for planters, shade structures for new plants, pedestals, and even raised beds can be made from trimmed-up branches and logs. Borders can be made by laying logs on their sides or standing them side by side. Both vertical and horizontal wood will quickly be adopted by insects like beetles, native bees, woodpeckers, and overwintering butterfly larvae. Areas below the logs can be amended to provide shelter for ground-dwelling wildlife. Adding small areas of different soils like sand or mulch provides areas for wildlife to dig into. Removing pockets of soils to create small open spaces will provide shelters in which animals can take refuge.

A sick birch tree (genus *Betula*) was cut down, but the owners knew the importance of snags and left a 5-foot-tall trunk. A new garden bed for full-sun plants was installed below to provide nectar resources for wildlife.

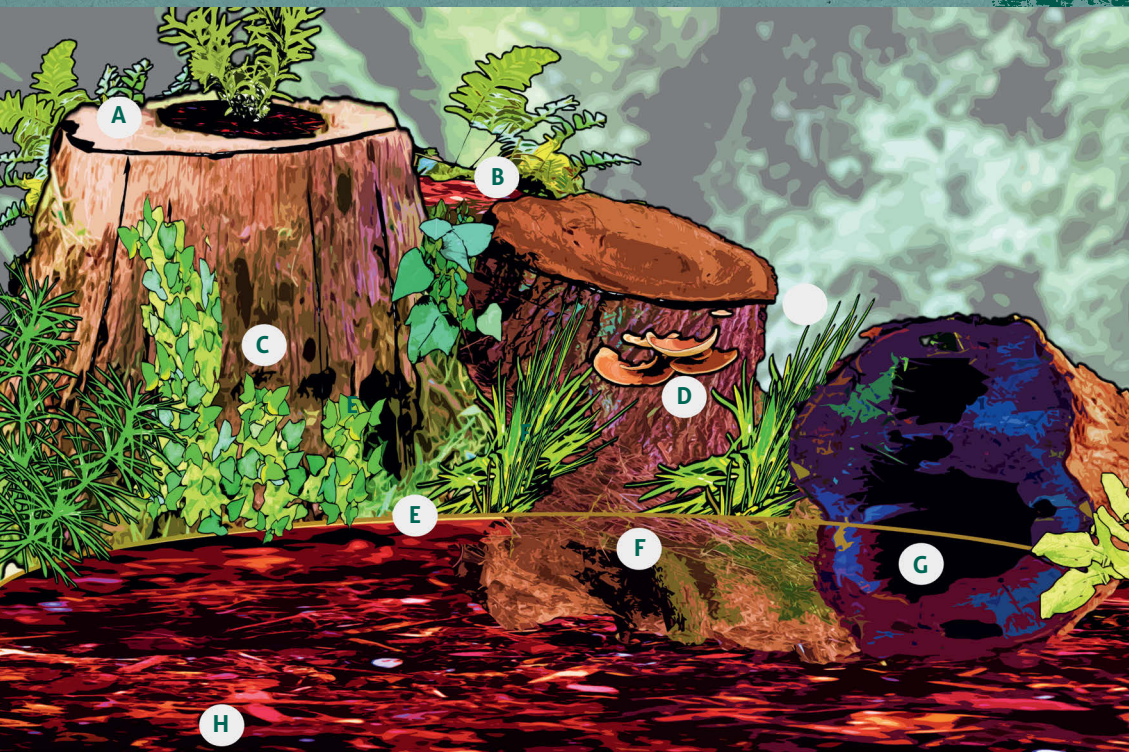
Large- and small-diameter logs line a path in Westchester County, New York. By using downed trees, the path was cleared, and local wildlife could utilize the resources. Similar designs can be used in gardens, especially between mowed paths in meadows and garden plots.

Tree trunks and large branches can easily be fashioned into pedestals for statues, potted plants, art, and birdbaths. If these are used for statues, you will need to replace the pedestal every few years because the wood will break down as organisms feed on it. However, they should be kept on the property so that species that need the wood in a more deteriorated phase will have the microhabitats for their life cycles as well.

A log pedestal supports a log wildlife shelter in a meadow-restoration project in Bedford Hills, New York.

A fallen Red Maple (*Acer rubrum*) was cleaned up by stacking branches between two stumps. Larger-diameter, shorter-cut pieces were placed on one side to create a large denning site for local foxes in Waccabuc, New York.

Fallen trees are regularly used by wildlife for temporary and yearly shelter. Near homes, when trees come down and they cannot be left as is, cut branches and trunks can be used to craft birdhouses, walls, and larger shelters for animals. Stacking the branches between two fixed posts is an easy way to make a log wall filled with microshelters. More careful planning can create a large opening where creatures like opossums, raccoons, and foxes can den.

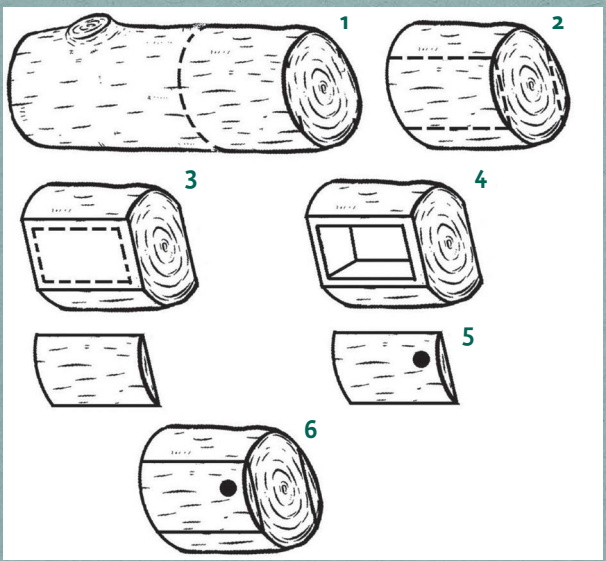


An illustration of a simple stumpery that mimics the microhabitats of stumps that break down. Designs can vary greatly, but key characteristics are labeled and explained. (A) Stumps and logs should be vertical and allowed to hollow out. Plants can be grown in the cavity with appropriate soil additions. (B) Raised soils between branches and logs add areas where animals can nest and plants can grow. (C) Plants like ferns and vines that survive in rich organic soils can be used to vegetate the microhabitat. (D) Mushrooms will establish and help break down the materials. (E) The soil line. Loose, organic-rich, and sandy soils should be used to secure stumps in place. These soils are important for some salamanders and many arthropods. (F) Logs should be buried in the soils to provide structure for burrowing animals and nest sites. (G) Logs and branches can be laid horizontally to mimic fallen trees. Hollow spaces above- and belowground improve sheltering options for wildlife. (H) Deep soils around the stumpery provide insulation and moisture gradients. In cooler regions, these should extend below the frost line by 6 inches (15 cm).

Smaller habitats can be made with a few large logs on top of and semi-buried in loose soils. This is known as a stumpery. Similar designs with smaller pieces of wood are commonly called bug snugs. Both additions mimic the natural decay of fallen trees and stumps that some animals, fungi, and plants rely on. Including ferns, mosses, and vines in designs can lead to stunning garden beds that also function as habitat for overwintering and nesting animals.

LOG SHELTERS

Using natural materials from our own or our neighbors' yards is an inexpensive way to improve habitats. Bird boxes and wildlife shelters can be created by carving large branches or logs with a chainsaw or a reciprocating saw, like a Sawzall. Openings to access the shelter can be modified for different wildlife. Securing these shelters



An illustration of steps to turn a log into a birdhouse.

Burrows, Caves, Crevices, and Rocky Shelters

In much of North America, species that make small and large burrows have historically existed, and some of these are common suburban inhabitants. A few of the smaller burrow makers include moles, voles, and chipmunks; medium-size excavating species include gophers, rabbits, and ground squirrels; and larger burrow makers include prairie dogs, Woodchucks, tortoises, American Badgers, and Coyotes. However, in residential areas and other urban environments, most burrowing animals are removed or killed and their burrows are filled. This in turn negatively affects any animal dependent on the burrows for their own shelter. Burrow-dependent animals include many that wildlife gardeners appreciate seeing, such as box turtles, lizards, salamanders, toads, and a myriad of arthropods.

Each burrowing species creates unique tunnels that can support different species of wildlife; many non-burrowing species readily use a suite of sizes. The good

at different heights, including ground level, will also support a wider diversity of animals.

Follow these steps to make a birdhouse:

Step 1: Using a chainsaw, cut a section of a log that is more than 12 inches (30 cm) in diameter to your desired length.

Step 2. Secure the log and make two cuts running the length of the log to create parallel faces (see the dotted lines in the illustration). The chainsaw will remove some of the log, and when these faces are reattached, there will be some exposed cut wood. This can be minimized by cutting portions of the log with the strongest curve. Save the pieces that have been cut off, as these will reattach to make the front and back walls of the house.

Step 3: Secure the log so that it will not move while you are cutting, and cut out the center portion of the log with four plunge cuts.

Steps 4 and 5: Remove the block from the log. Then drill a hole into one of the faces that were cut in step 2. This hole should be carefully measured for the wildlife for which the house is being made.

Step 6: Attach the cut ends with screws, and the box is ready.

A family of marmots (genus *Marmota*) hang out around their burrow.

A recent burrow excavation in Texas with fresh dirt at the foot. Birds regularly search these turned soils for insects and seeds. In addition to the burrow builder, the burrows will be used by a variety of wildlife.

news for our gardens is that it is fairly easy to re-create abiotic refugia that support a diverse array of wildlife. Conversely, our makeshift burrows won't have the same complexity or support the species that use recently excavated soils to hunt for grubs or build their nests, which is all right.

Underground shelters are important because they offer microclimates that are cooler than sunbaked areas, refuge from larger predators, and nesting sites for many animals. When you add underground shelters to your garden, wildlife will be able to better exist in your area and maybe even take up residence so that you can view them day after day. There are many ways to create underground shelters, and you can design them to attract certain wildlife over others.

A rabbit sits outside a drainage pipe it has made its home instead of a burrow. These pipes can be used in gardens to create underground shelters that mimic burrows. Make sure to cut an excess of holes in the bottom to allow for draining.

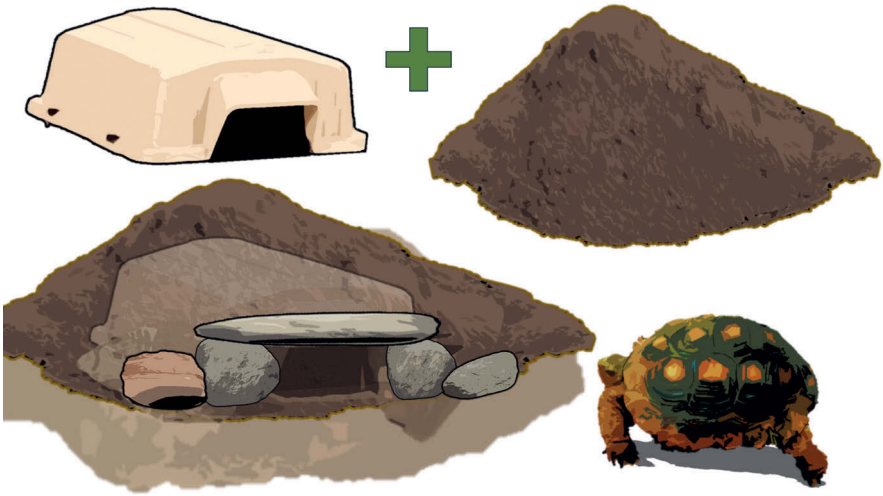
An illustration of a raised planter with a burrow installation. The dotted white line indicates where shallow rooted plants could be placed to further mask the opening.

Burrows and makeshift underground refugia can be easily constructed under other projects like raised beds, rockscapes, and small terraforms like mounded garden beds or sides of slopes that are part of the landscape design. It is best to build the burrow before installing the project covering the area, as the soil and materials can be placed over the burrow. The final feature should reach at least 18 inches (45 cm) below the covering soil. Another option is to excavate an area, build the wildlife tunnel, and cover it over again. Extending features farther below the soil surface to extend below the frost line creates more natural environments with which animals can thermoregulate, especially in ecoregions with colder winters. Entrances and hollow spaces should be away from where people walk, cars drive, and pets so that wildlife feel safe using the feature.

Designs for burrows should include strong walls and ceilings and porous soil floors. This can be achieved by making walls with sturdy rocks or bricks and covering the burrow with a flat, sturdy top. For smaller-diameter burrows, use clay, PVC pipes, or corrugated tubes for a tunnel-like construction, but it needs to be modified so that water will drain. Floors of burrows should not collect water. If impervious materials are used, drill a large number of holes to allow water to drain into the soil. Tunnels made for larger wildlife—like Raccoons, foxes, box turtles, and tortoises—should be a minimum of 2 inches (5 cm) wider and taller than the animals' widest and tallest measurements. Additionally, areas should have soft soils at the bottom and at the end of the tunnel for larger wildlife. Another way to think about the dimensions is that an animal should be able to turn around inside the space. If possible, design the burrow with a slight upward slant or dip to prevent water from filling the chamber in torrential rain events, or place it on a slope.

— Underground Shelters, Wildlife Burrows, and Rock Shelters

Like burrows, underground shelters are most easily installed under projects before those projects are started. Although these structures still might include a burrow entrance that should be in a somewhat protected area, underground shelters create



In tortoise (family Testudinidae) conservation, a common den structure is the top of a large dog kennel, covered in soils and disguised with boulders. Similar structures can be made with smaller kennel tops to encourage box turtles, toads, opossums, and foxes, among other wildlife.

a room or den underground. These mimic the structures that some mammals create in their complex, underground systems, as well as small subterranean caves. The chamber must have a sturdy ceiling and walls, but the floor should be exposed soil, at least in part. Upside-down totes, old pet carrier tops, and even buckets or pots with a large hole in the side can be used to make sturdy, inexpensive shelters. Limiting the entrance dimensions will improve thermal insulation and restrict which animals can access the space. Similarly, providing a depression in the rear of the area will create a more stable temperature that holds cooler air in summer.

The bare floor should be sturdy but loose enough for animals to dig into. Adding leaf litter or straw will also allow animals to bed down. Many animals cover themselves in soil when hibernating, so make sure the soil is loosened 3 to 9 inches (7.5–23 cm) deep. If there are particular species of wildlife you do not want using these shelters, like Raccoons and skunks, make sure to keep entrances suitable for target wildlife but smaller than the species you do not want to attract. In some cases, it will not be possible to prevent larger, non-target wildlife from using the refugia.

— Shallow Shelters

Soil-texture diversity is important to include in overall designs, but especially under and around rockscapes and permanently placed pots and objects. This is because the

A non-native Brahminy Blind Snake (*Indotyphlops braminus*) frantically searches for new shelter after a pot is moved. Although not intended as such, unintentional shelters are common in gardens; they can be improved with thoughtful placement and by including microshelters and soils into which animals can burrow.

aboveground features provide protection and structure for burrows and nests that animals can excavate themselves. Soft, sandy soils are used by reptiles and amphibians for egg laying and possibly overwintering. Harder clay soils are more favorable for use by burrowing insects, earthworms, and many arthropods. Areas of soil under features can also be intentionally excavated for lizards, toads, beetles, and other digging organisms to be able to dart into. Most gardeners have lifted an object in their yard that has settled and formed a tight seal with the soil. Although settled objects provide microhabitats sought after by a variety of wildlife, like earthworms and some nesting bees, small chambers are important refugia for many wildlife that do not dig. Providing

The smooth soil, expanding and contracting due to changes in temperature and moisture, below an object that sits undisturbed for months creates microhabitats that some soil organisms, like worms, utilize. Disturbed objects provide microshelters that many small wildlife need. Large animals, like bears, Raccoons, and armadillos, regularly disturb objects, which prevents settling.

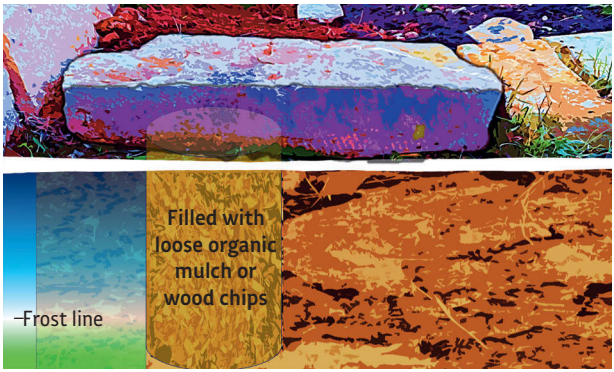
stable soils for the above objects while including a small hand-size divot or two will not affect the stability of the area, but will provide more resources for wildlife.

— Rockscapes

Rockscapes include the use of stones and boulders in landscape designs. They can be focal points of garden beds, borders, and retaining walls, or blended into the topography. Stones create important sheltering resources for a diversity of wildlife, and designs that plan for wildlife use drastically improve the habitat. Larger stones can be used as stand-alone features; small and medium-size rocks are great for borders along garden beds and paths. Most stones with dimensions greater than 6 inches (15 cm) across can provide shelter for wildlife. Soils below both isolated rocks and grouped stones should be amended for target wildlife species. Simply creating pockets of mulch under parts of the stones can significantly increase sheltering spaces for wildlife. Keep in mind that stones that are balanced or "standing" should not have soils modified for wildlife without secondary supports to prevent the rocks from falling over.

Borders made with stones can be disturbed every few months to help prevent the rocks from settling. Tilting rocks and setting them down again mimics natural

A dramatic example of stone use in a garden, this park design includes towering stacks of rocks among native and horticultural plantings. Close inspection of these stacks revealed numerous animals using them for shelter, even though they were not intended for wildlife use. Preserving crevices, microshelters, and cleared spaces provides much-needed shelter for organisms in developed areas.



How to hide important sheltering resources under stones. Clearing out deep areas and filling them with organic matter replicates decomposing tree trunks and adds key overwintering sites to urban landscapes. In colder regions, these should extend below the frost line for animals to escape the freezing temperatures.

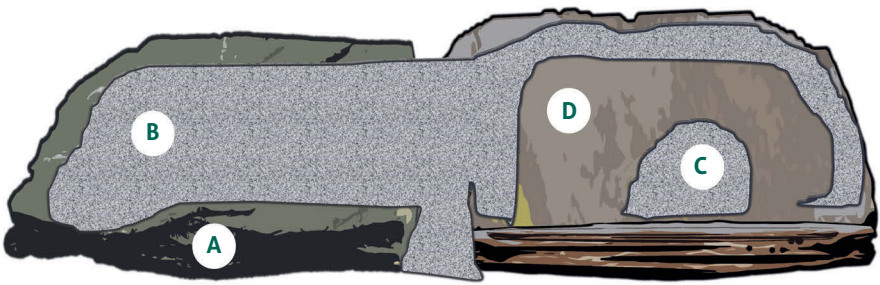
disturbances caused by bears and other large foraging wildlife. In the wild, extirpated omnivores regularly moved objects while looking for food. This creates new spaces between the undersides of objects, and the soil that smaller wildlife shelter in. Disturbing stones every few months helps re-create these valuable shelters. Adding a small amount of organic material, like garden trimmings and fallen leaves, before placing the rock back in place further adds microhabitats to the garden.

When building a multi-stone rockscape, use the same type of stones for a more natural look. If the planned feature will be stacked, make sure layers are stable and will not shift under the weight of larger animals that may investigate the area or try to hunt there. An option is to use stones that have naturally flat areas, such as sandstone, slate, and limestone, for taller rockscapes. Before placing the rockscape, dig down 6 to 12 inches (15–30 cm) to loosen the soil. Amend the soil for the target wildlife, if necessary. The area can have a combination of soil types for every square foot it covers. Sandier soils make it easier for animals to burrow in (post-construction), while silt and clay soils are used by insects and sunning reptiles. Once the soil is ready, smaller base rocks can be placed to create small caves and crevices under larger base rocks. Or, if the rockscape is not intended to provide shelter, large base stones can be either placed on the surface or buried down a bit, which creates a different habitat for other animals to use.

No matter which type of rock is chosen for the design, a variety of animals will use the area. Designs can easily incorporate sunning rocks for reptiles, low perches for birds, feeding areas for chipmunks, and shelters for various soil invertebrates below. If the design includes disturbing the soils below the rocks, lizards, toads, bees, and other arthropods will likely shelter there or create nests under the rocks. For different soil treatments, refer to the "Soils" section in chapter 1 and the various wildlife profiles.

Aboveground, rockscapes in full or part sun attract lizards. This is because most lizards and other reptiles need sunning areas to warm up. However, sunning exposes

Depiction of a stacked stone border that can be modified to support more wildlife. (A) Cross-section of a stone garden bed border. (B) Plant roots growing through the soils held by the rock barrier. (C) A transparent rock to indicate openings in the wall that allow animals to access the soils. (D) Soil diversity extending under rocks to support spaces and provide nesting areas for bees. (E) Deep soils for plants to root into and animals to seek refuge in. (F) A forward support creating an open cavity in the rock barrier where animals can seek shelter. Building these openings near the base increases overall moisture, as openings near the top tend to be drier. (G) A salamander (order Urodela), representing animals that seek shelter in damp areas.



How to intentionally provide gaps in stone walls for animals to shelter in. (A) is the stone layer, on which (B) mortar is placed for a second layer of rocks. Mortar placed around the outside and an island (C) of mortar supports the next layer of stone and creates a sizable crevice (D) that animals can take refuge in.

Rockscape in a garden in west Texas intended for small wildlife use. Horizontal crevices were created with small rocks between large heavy stones to provide refuge and stabilize the structure. Below, organic debris is placed in an aboveground cave, with sandy soils beneath for animals to burrow into.

these animals to predators. Depending on the species of reptile, the animals sun on rocks or exposed ground. A well-designed rockscape can provide both. Good sunning areas have three main components. First, an area that is larger than the size of the target species should be exposed to the sun. Second, there should be nearby shelter into which animals can dart when they are startled or when a predator approaches; this can include nearby plants, burrows, and space between soils or between stacked rocks. Any refuge cavity should be secured so that animals cannot be accidentally squashed if a predator, like a cat or a Raccoon, jumps on top. Third, the area should be far from standing water, as reptiles can get stuck to the rocks as their skin dries.

In wetter regions and forested regions, rockscapes can be designed primarily for shelter as well as temporary water-holding features. Rocks with large divots or depressions can allow rain to temporarily pool in those features, and they can then be used by wildlife for bathing, drinking, and soaking. When placing these rocks, it is important to make sure that the water stays in the shade to prevent animals like toads from getting stuck to the rock surface as they dry out. For shelters, the same rules apply for the sunning rocks. Top rocks should be sturdy and heavy, with areas for animals to dart into when they are startled.

A natural rocky outcropping on top of a hill used by birds for perches and lizards for sunning.

SHELTER DESIGN

Choosing areas where wildlife can take shelter is just as important as providing native plants. During the planning stages for garden projects, a good approach to facilitating wildlife is to include areas that replicate habitats that target wildlife would choose in the wild. Another way to think about this: If you were looking to see the target wildlife on a trail, where would you look? Do they regularly hide in specific types of places? For example, if a garden design only has garden beds, benches, and a birdbath but targets wildlife including lizards and beetles, where are those animals supposed to sleep, nest, and overwinter? Which areas in their habitats would they be found in throughout the year? Once these questions are answered, then ask whether those areas or structures or resources are available in this design or nearby. Most of the spaces where wildlife spend their time are a form of shelter. Intentionally providing shelters can create gorgeous structures, keep wildlife safe, and add beauty to the landscape. Below are a few options for shelters that can be added to gardens.

Small Cave or Crevice

Small cave and crevice designs for tinier animals like salamanders and lizards can involve large flat rocks, or a series of smaller flat rocks that function as the ceiling and floor. The space between the rocks can be made by placing small rocks or lines of soil between the top and bottom rocks. Leave one side exposed to the air and cover with soil, mulch, or other rocks for insulation. Keep in mind the moisture requirements for target species. Amphibians need damp areas, while lizards prefer drier conditions. These areas will also host a number of arthropods and possibly solitary nesting bees.

Toad Abodes

Toad abodes are simple, beneficial shelters that various wildlife groups have promoted. The shelters are generally aboveground but can be covered in soil as well. The most simplistic design is a small terra-cotta pot, turned upside down and supported by rocks on top of

A gopher snake (genus *Pituophis*) shelters in a corner of a porch. Intentional shelters help keep wildlife safe and prevent surprise encounters.

Mortar-free stone wall with stable rocks and many crevices for wildlife to utilize. These can be built in damp, shady areas to improve moisture and in areas with full sun to keep wildlife warm.

A simple setup for a toad abode with an upside-down terra-cotta pot, in the shade and with space below for toads to enter. Covering pots with mulch helps retain moisture and prevents sun exposure.

loose soil, in a shady location. It is crucial that the pot not get direct sun because it can turn into an oven. Extra layers of mulch, leaves, or rocks can be placed around the pot for more protection. Leaves, sand, or mulch can be placed under the pot for toads to further nestle down into; they can be moistened every so often to help keep the space damp.

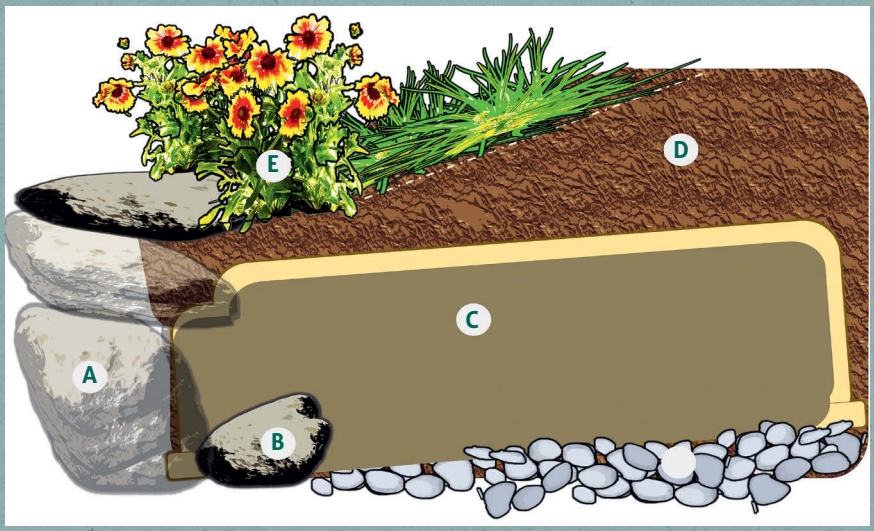
Large Cave Designs

Bigger cavernous designs can be made with large flat stones for ceilings and floors, but lighter materials like polyurethane structures might be more feasible. Another option is to create a mold with a pile of sand, carving patterns and structures mimicking stalactite-like shapes and support columns. Then use appropriate support infrastructure like wire mesh and pour cement for the final shape. Once dry, remove the sand to expose the cavernous structure.

continued overleaf

SHELTER DESIGN *continued*

Much like the smaller underground shelters, large cave designs need space for grading slopes and supporting insulating materials around the chamber. Entrances can be disguised with rocks, logs, and soil, but the larger entrance makes the internal conditions similar to outside conditions. This makes it harder to insulate from winter temperatures and ambient summer heat, so smaller overwintering structures should also be worked into the property.



Makeshift caverns can easily be installed under raised beds and on slopes. (A) Entrances should be at the lowest part of the cave to prevent flooding. (B) A ledge or lip near the entrance helps keep the interior at a more stable temperature. (C) The opening should extend deep enough to prevent freezing in winter or overheating in summer. Substrates at the bottom of the cave should be pervious. Loose soils also help animals that want to nestle down. (D) Soils or mulch can cover the chamber and should insulate all areas above and to the side. (E) Areas to the side can be planted with deep-rooting plants, and shallow soils on top can be planted with grasses or covered with trailing vegetation.

— Rock Crevice Gardens

Garden magazines and designers have recently come across a rather common form of gardening in rocky terrain, known as "crevice gardening," and have developed new techniques that enable the growth of many horticultural plants within rock-garden designs. The overall approach has been utilized for centuries by people living in extremely rocky terrain, who excavate areas to grow plants between rocks. Crevice

Hollow Logs and Branches

In habitats where mature trees or thick-stemmed shrubs are common, so are hollow branches and logs. The hollow spaces are used by all sorts of animals for shelter, nesting, overwintering, and even hunting, especially when these structures are on the ground. Adding hollow logs or branches to the landscape can be done covertly or conspicuously. Hidden additions can be placed behind taller or trailing plants, tucked into holes or low spots, as well as used to retain soil along hills. More visible options include incorporating them into walkway borders, planting short, low-growing plants around the base, or even placing them in barren areas as a focal point. The difficult part is finding a source for the hollow logs, as they are rarely for sale and wood should not be moved between counties due to the risk of introducing invasive insects and pathogens. Luckily, tree-trimming companies sometimes work with interested buyers to set aside and deliver hollow trunks and branches.

As with other sheltering areas, the size of the opening determines the wildlife that can utilize it. It is also important to keep these structures away from roads and busy foot traffic so animals can feel safe. Secondary shelters can also be created below the logs with amended soils and intentional cavities that other animals may enjoy using. Adding hollow logs to various garden habitats also diversifies the garden microclimates, so consider adding pieces to spaces with different light and moisture levels.

A vertical, hollow log stands in an agricultural field. The low entrances are accessible to ground-based animals like foxes and raccoons, while entrances higher up are accessible to bats, birds, and agile, climbing animals. Sometimes, local tree companies can provide hollow logs that can be laid horizontally for garden designs.

gardens utilize deep soils between stones that extend at least 6 inches (15 cm) into the ground. Soils between rocks benefit from the surrounding rocks as water runs off the stones, increasing the overall water availability. The impervious, vertical surfaces under the soils also direct the water and roots deeper into the soils, which allows for better survival of plants between rain events. Tops of stones can also stand above the soils, creating microhabitats and shading soils. The height of rocks protruding out of

A natural rock formation with soils building in crevices. A variety of plants and animals use these spaces for their life cycles. Using natural formations like this as inspiration for rockscape and crevice-garden design can really bring out the natural beauty of a garden.

the soil surface can range from a few inches to a few feet, depending on the plants and the desired microhabitats. Arranging crevices in an east-to-west orientation provides northern and southern exposures on soils; an east-west alignment keeps soils to the north of protruding stones shaded all day. North-to-south designs can provide microclimates driven by morning and afternoon sun; gaps that run north to south allow soils to be shaded most of the day next to rocks that protrude a few inches above the soil. Orientation of spaces between stones can be linear or wavy, short or tall; the design should consider the wildlife and plants being catered to.

Building a crevice garden in non-rocky areas is fairly simple. Any variety of rock can be used as long as pieces are more than 6 inches (15 cm) in one dimension. Rocks must be placed close together, with gaps between them no less than 2 inches (5 cm) and up to a foot (30 cm). Larger spaces can be left in some areas for larger plants or if your design simply looks better with them, but keep in mind that soil moisture will decrease as the gap sizes increase. Areas between rocks will be filled with soils for plants to grow. Fill materials can also be selected to promote animal nesting and overwintering. To better diversify soils for wildlife, use various soil types between gaps. Sandy soils and organic materials in some gaps provide nesting and overwintering areas for wildlife. The spaces between stones do not have to be perfectly vertical; stones can extend above the soil surface, and soils in each crevice can differ in height.

As you choose soil types to place between the stones, you should be influenced by the possible habitats that could occur in the area and which wildlife species may utilize the space. For example, sandy and gravel-filled soils can be appropriate for wet areas, including around water features, loamy soils are common in deciduous forests, and clay soils are abundant in many soil pockets around exposed bedrock. Soils should also be chosen based on the plants selected for the crevice. Cacti, for example,

Illustration of a crevice garden using thin, vertical rock faces to separate soil types and direct roots and water deeper into the soils. Such designs help reduce evaporation and are gaining popularity in arid regions. Designs can include soils for nesting bees, refuge for small wildlife, and specific soils for different plants.

Boulder crevices along the Yuba River, in California, with rhizomatus Umbrella Plants (*Darmera peltata*) growing in pockets of soils. These plants regularly grow in areas that receive flood waters.

Pairing rockscapes and soils in various habitats builds structure and habitat. In the Missouri Botanical Garden, in St. Louis, soils packed into crevices between rocks support a variety of wetland plants, amphibians, and insects, while also being absolutely stunning to look at.

need well-draining soils, while many ferns do well in organic-rich soils with heavy water retention. Even though drastically different soils can be placed in adjacent crevices, care should be taken when placing plants to ensure they grow well together and have similar light and precipitation needs. As plants establish and wildlife move in, crevice gardens can turn into very active areas that are absolutely worth the effort.

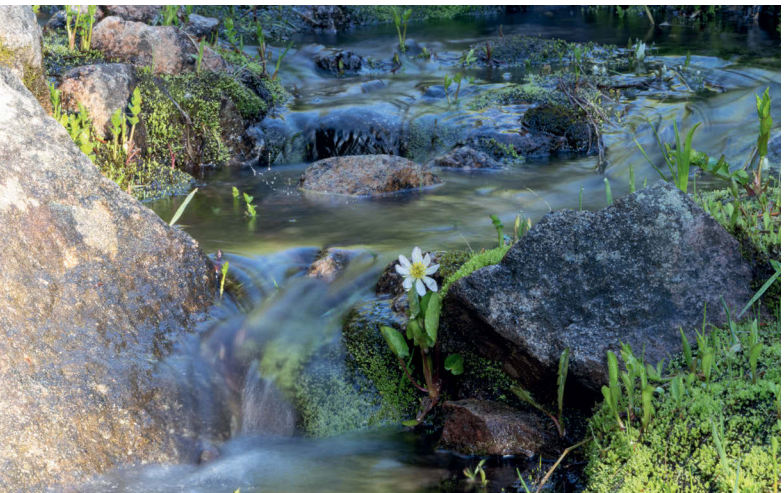
Water Resources in the Garden

In gardens, water features are easy to add but are more effective if they mirror natural water resources for the landscape. Swimming pools, for example, are a water resource that does not mimic natural water features. Common pool designs include vertical walls with an overhang, which prevents wildlife from crawling out or even finding refuge to save their energy. Additionally, the water itself is treated with chemicals that often kill invertebrates and algae. Keep in mind that some natural water features can be dangerous. Wild landscapes can have hazardous raging rivers, waterfalls, and pools of water with steep sides that animals navigate around. However, just because a feature is risky for one species does not mean it is for another. In suburban landscapes,

A small stream flows over a root crown and boulder in Nevada. Similar garden features are easy to re-create to provide aquatic habitats.

a fast-moving waterfall feature can harm amphibians accustomed to slow-moving streams and vernal pools that would naturally occur in their area. That same stream could be perfect for raccoons, deer, fish, and some insect larvae. When adding water resources to gardens, keep in mind the types of features that were once common in the area. To reduce risk to as many animals as possible, make sure that there is an easy way for small animals to climb out and that pumps are behind screens, filters, or barriers, and keep the water clean to prevent disease spread.

In more arid regions, perennial water resources are currently not abundant in most natural landscapes. Historically, however, more water flowed through rivers, with seasonal and perennial springs hydrating habitats. Overuse of groundwater has caused most springs to dry up, and agricultural pumping and drinking water reservoirs have severely reduced flow in still-active springs. Although there are naturally occurring, perennial water resources in arid ecoregions, those microhabitats are difficult to



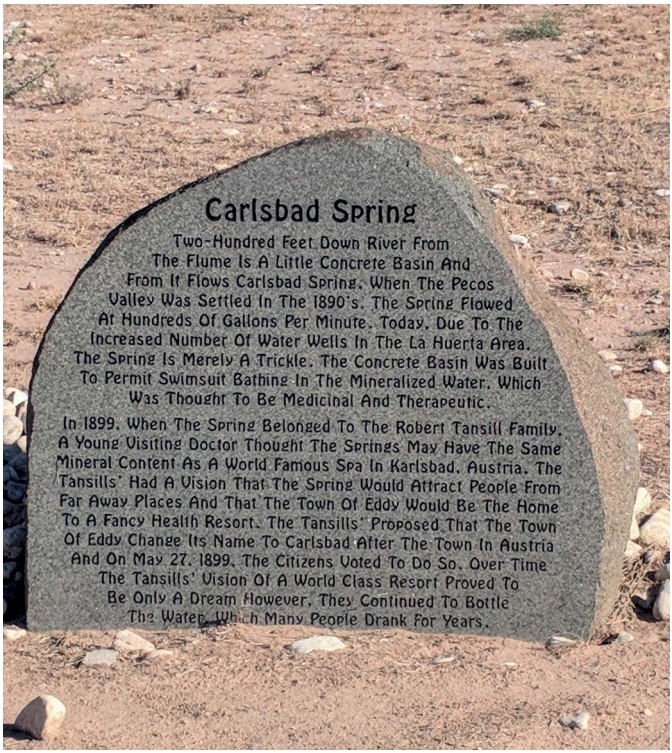
A natural babbling brook is home to a diverse array of insect larvae, crustaceans, and fish. Re-creating habitats like this requires pumps and engineering, but they are incredibly beneficial to local wildlife populations.

A dried-up perennial spring south of Grandfalls, Texas. Historically, this spring was home to an active village, likely of the Lepai Nation, and a population of now-endangered pupfish (family *Cyprinodontidae*). Groundwater pumping lowered the water table, killing this entire habitat and many others in the region.

mimic when trying to conserve water. More abundant in the landscape (and easier to replicate) are short-lived water resources like vernal pools, playas, and rock-lined ponds in streambeds, where water stands after rainstorms for a few days to a few weeks, even, rarely, for months. Seasonal springs typically flow after snowmelt from nearby mountains increases water tables and after monsoons raise them. Since most animals native to arid and semi-arid regions are accustomed to long dry periods, creating vernal pools in your landscape, instead of large perennial bodies of water like ponds and open fountains, can help support native wildlife while discouraging common non-native species. Design options and ideas are presented in the section "Rain Gardens and Bioswales," which appears below.

Ecoregions that receive precipitation throughout the year have more frequent and a greater of variety of perennial and intermittent water resources in the landscape compared to drier regions. The types of water resources gardeners can provide in wetter regions run the gamut from simple birdbaths, to disappearing water fountains, to full-on artificial creeks and large ponds. In North America, many of the wetter environments still have vernal pools that form in depressions. These pools are incredibly important for amphibians, dragonflies, and a variety of arthropods that are preyed upon by fish. In a garden, vernal pools can easily be integrated into the landscape. Wise use of water options includes feeding these areas with runoff from rooftops and other impervious surfaces. The most common landscape design features that include ephemeral ponds are rain gardens. When constructed properly, the pools can hold water for a little over a month and will be used by frogs, salamanders, toads, and

One of the major springs that feeds the Pecos River, a desert wetland corridor in New Mexico and Texas that was historically much larger and is still important for wildlife migration, is merely a trickle of its former flow. This monument, near La Huerta, New Mexico, explains how it went from hundreds of gallons a minute to its current state. What is not conveyed is the incredible habitat loss locally and for hundreds of miles downstream.


Carlsbad Spring
Two-Hundred Feet Down River From
The Flume Is A Little Concrete Basin And
From It Flows Carlsbad Spring. When The Pecos
Valley Was Settled In The 1890's. The Spring Flowed
At Hundreds Of Gallons Per Minute. Today, Due To The
Increased Number Of Water Wells In The La Huerta Area.
The Spring Is Merely A Trickle. The Concrete Basin Was Built
To Permit Swimsuit Bathing In The Mineralized Water, Which
Was Thought To Be Medicinal And Therapeutic.
In 1899, When The Spring Belonged To The Robert Tansill Family,
A Young Visiting Doctor Thought The Springs May Have The Same
Mineral Content As A World Famous Spa In Karlsbad, Austria. The
Tansills' Had A Vision That The Spring Would Attract People From
Far Away Places And That The Town Of Eddy Would Be The Home
To A Fancy Health Resort. The Tansills' Proposed That The Town
Of Eddy Change Its Name To Carlsbad After The Town In Austria
And On May 27, 1899, The Citizens Voted To Do So. Over Time
The Tansills' Vision Of A World Class Resort Proved To
Be Only A Dream However, They Continued To Bottle
The Water, Which Many People Drank For Years.

A perennial, babbling brook running through the deep shade of a forest.

various insects, including dragonflies. Placing these features in part shade is recommended, as is surrounding the area with plants so animals can escape the heat of the sun. Aerating pumps, like solar birdbath pumps, can also be added to improve water quality, but make sure intakes are screened off and water flow is kept low. In drought years, supplementing the water until larval forms metamorphose into juveniles may be necessary.

Fishless perennial features, as well as ponds with fish, can be made in the same manner as the vernal pool. You must have a chlorine-free water source for filling the pond. The banks should rise above the water level with rough, lightly sloped areas for animals to crawl out. For designs that allow overflow when rains are too much, make sure to have a screen that allows water to pass through but keeps aquatic wildlife in the pond. Perennial ponds are also great for plants that can benefit pollinators, such as Aquatic Milkweed (*Asclepias perennis*), pond lilies (genus *Nymphaea*), and sedges (family Cyperaceae) for birds.

A native landscape rain garden and bioswale in Oregon. Small-scale rain gardens can be planned to channel runoff from hard surfaces like roofs and driveways into areas with plants that prefer sporadic inundation.

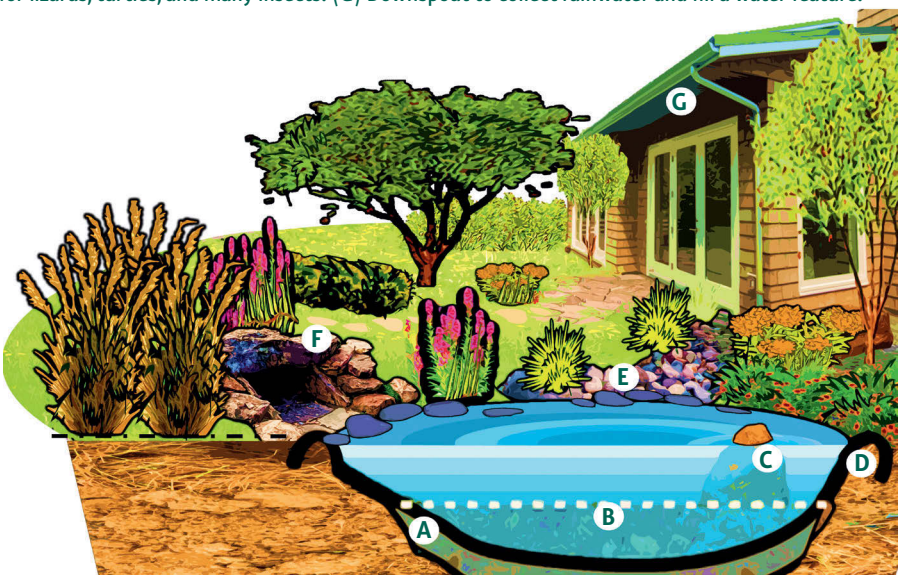
A pedestal birdbath next to logs laid out for habitat resources. The logs are good habitat for salamanders, frogs, and toads, but the water resource is unavailable to all the species that cannot climb.

When providing water, make sure to consider access for all wildlife. Most animals, including insects, are accustomed to water at ground level, so providing a shallow dish will hydrate most species. Elevated features like birdbaths are used by different animals that can fly or climb well and mimic water held in tree hollows. Shading water features is recommended to reduce algal growth and keep water oxygenated. Direct sun and high temps turn the water anoxic, meaning that oxygen will not be dissolved in the water and that gilled animals, along with plants, will perish. Very few aquatic species can survive in anoxic water, so wetland habitats should be deep, include pumps for aeration, and be adequately shaded. Shade can be provided by emergent or overhanging plants, rock features, pathways, sculptures, or structures.

— Rain Gardens and Bioswales

Urban areas are filled with impervious surfaces that create runoff during rain events. These surfaces include roofs, cement, asphalt, and compacted surfaces like dirty roads

A yard design incorporating roof runoff and amphibian breeding habitat. (A) Amended soils to support the pond liner. (B) Substrate within the pond area for animals to hide in. This substrate also hosts eggs of invertebrates that can dry out in seasonal ponds. (C) Emergent structure that provides safe escape from the depths and perches for animals wanting to dart back into the water. (D) Tucked underlining to prevent exposure and animals digging below and getting trapped. (E) Cleared, low-gradient escape and viewpoint from the patio. (F) Nearby cavernous shelter for wildlife to take refuge in. Adding mulch or sand around these areas improves nesting site availability for lizards, turtles, and many insects. (G) Downspout to collect rainwater and fill a water feature.



A bioretention display garden in Stillwater, Oklahoma. Rainwater is diverted to the pond to capture sediments and pollution before spilling into a dry creek bed. Designs like this help clean water and improve local habitats.

A well-designed, narrow water feature using the same aesthetic as a dry creek bed. Similar designs can be used to channel runoff and include native plants along the sides.

and gravel driveways. With a little planning, runoff can be directed to pool into specific areas, known as rain gardens, which reduce local flooding and erosion and help the environment. The key elements of rain gardens are soils that allow water to percolate into the ground and plants that tolerate both dry seasons and flooding. Some rain gardens also have spillways that allow water to continue downstream. These designs, called bioswales, can help filter out pollutants and still be planted with native plants to provide habitat for wildlife.

A variety of designs for rain gardens are easily found on the websites of conservation organizations and extension offices. Most designs do not specifically explain how to incorporate year-round shelters for animals that most benefit from periodic flooding. Dry creek beds leading to depressions can make dramatic, gorgeous features as well. Make sure to add species-specific shelters for both breeding seasons and hibernation, as well as appropriate prey habitat for the animals you want to encourage in your garden. Species-specific needs are discussed in chapter 3.

— Damp Areas

Damp habitats are critical to the survival of many animals, especially invertebrates and amphibians. Damp habitats are areas that retain moisture but are not flooded, which enables amphibians and invertebrates to retain water and breathe. Most often, around homes, animals that require these areas live in spaces that are unintentionally provided, like under pots, near faucets, and around compost bins. Unfortunately, these spaces can sometimes lead to harming or even killing the animal on hot summer days or as pots and compost are moved. Intentionally providing damp spaces improves their chances for survival. In most regions, supplemental watering of the area is necessary; making sure irrigation can occur is important when deciding where to locate these wetter habitats. Smart pairing of these resources near other features and plants that require water can save time during maintenance.

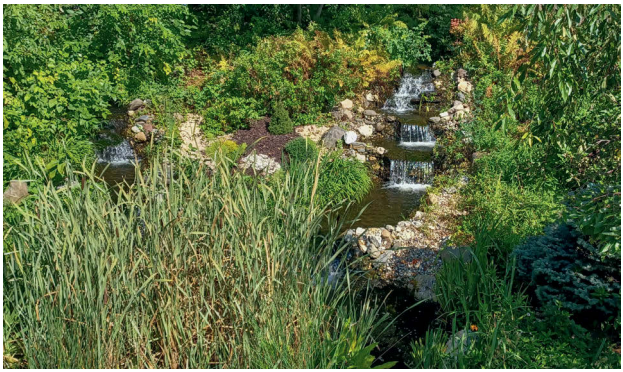
A damp microhabitat suitable for fern and moss growth also hosts salamanders and a variety of invertebrates. Damp areas in gardens are important for supporting populations of anthropods and amphibians.

Shaded areas below trees often support damp habitats. Moss and fern growth are good indicators of higher moisture levels. Landscaped areas can also have damp areas around irrigation, runoff channels, and heavily shaded areas near buildings.

There are different types of damp habitat, but most occur near riparian and wetland areas in the wild. Some naturally damp spaces include sandy refuges between rocks, areas where late-stage breakdown of organic materials occurs, especially in forests, and soils along wetland edges. In a garden, there are a few options for designs providing damp areas. Underground options include filling an area with organic-rich, loose soils and covering them with a shading structure, like raised rocks, large logs, potted plants, shrubs, and even trees. Similarly, excavating areas that extend below the frost line, filling them with mulch, leaves, and loose soils, and then regularly wetting down the area mimics the breakdown of large tree roots. Be careful when adding moisture as overfilling an area can drown animals inside, especially non-motile pupae and eggs. Aboveground features include slow-compost and leaf piles, as well as rocky features near irrigated plants. Piles of mulch can be wetted regularly to encourage breakdown, which also keeps areas inside damp for animals. Flat rocks, like flagstone and slate, can be stacked with layers of gravel and sand between them. A similar option is to lay flat rock vertically or near vertically, as in a crevice garden, and fill areas between them with different types of soils and organic matter that retain moisture.

— Ponds, Fountains, and Birdbaths

If there are no water features around your area or if you simply want to create your own water feature to attract wildlife, there are many options to choose from. Water in urban environments can be dangerous for many species unless some care is taken. Containers that hold water for any length of time should have low-grade, rough escape routes for animals to crawl out on if they fall in. As stated earlier, access to water should also be considered. Birdbaths are great for flying animals and some climbers,



A landscaped creek with herbaceous plantings. Garden designs can support wildlife that prefer streams, but keep in mind plumbing and electricity are needed.

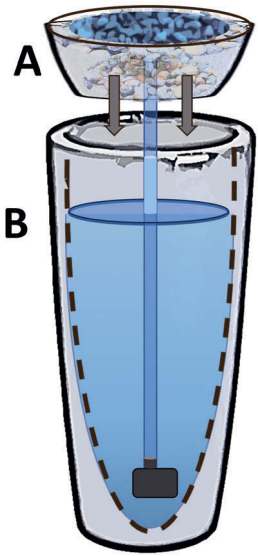
but ground-dwelling organism like toads, box turtles, and many lizards are unable to scale tall vertical surfaces. Providing water at ground level is most important for any habitat. Higher water resources like fountains and birdbaths are wonderful secondary options to attract wildlife and create focal features.

Water features at ground level can include shallow dishes, divots (small depressions like hoofprints), and depressions in rocks that hold water after rain or irrigation, ponds of all sizes, and wetlands. Shallow dishes and divots should be cleaned regularly to prevent disease spread and can be allowed to dry out between filling and left to fill during rain events. Seasonal ponds and rain gardens that support wildlife life cycles should be left alone as much as possible but may require additional water in drought years. Perennial ponds and wetlands should be monitored to make sure no problems are building up; they may require annual cleaning, depending on their setup. Keeping live plants, soils, and aeration in these features will help promote natural cycles that support healthier habitats.

In this garden setup, a large disappearing water feature provides some ground-level access to water where the streams pass through the gravel. Hidden exit passages in the design help animals escape and unintentionally provide shelter for many toads and frogs.

Disappearing and pondless features are great for adding the sound of water to an area. These features also save water as they reduce evaporation, which is especially useful in arid and semi-arid regions. Many animals are able to drink from these types of water features, and the majority of the water volume is kept out of sunlight. Well-designed features also prevent animals from drowning, but many designs do not take animal welfare into consideration. Make sure the basin has an escape (e.g., a rough surface from the bottom of the basin to an exit point) and that pumps are behind screens.

Kits for building disappearing water features of all sorts are available for purchase, as well as a variety of build-your-own tutorials. The concept is quite simple: an underground or hidden reservoir holds most of the water and a pump, which is covered in a way that water can flow back in, with or without pooling. Setups range from simple pots with rocks on top to elaborate fountains. Most commonly, the cover is a screen with small mesh that is strong enough to support the water feature structure. This can be done with minimal cost, but some designs can be very expensive. An elegant,



ABOVE LEFT: A simple disappearing water feature can be made using two planters, a pipe, and a pump. A small planter (A) can be set on top of a sealed container including another pot without drainage holes (B). A pipe attached to a pump bubbles water over rocks on the top planter and drains it back into the reservoir. This is a great way to prevent mosquitoes and evaporation while providing water to organisms.

ABOVE RIGHT: An elaborate water feature with a large hidden catchment. This provides water for many terrestrial organisms while preventing aquatic larvae from establishing.

yet inexpensive design uses a tall, watertight pot as the basin. A solar or plug-in water pump with tubing is placed inside, and a shallow pot with a drainage hole is placed on top. Make sure there is enough room or additional holes for water to flow back into the reservoir. The shallow pot on top can be filled with rocks, wood, or even plants in a way that allows water to be reached by animals for drinking and bathing.

Adding water to your landscape can have some drawbacks. For example, many predatory wasp species are attracted to water resources to help them make building materials for their nests. These wasps will then hunt in your garden and can decimate invertebrate populations, including the caterpillars that many gardeners want to have in their yard. Standing water can also function as mosquito breeding habitat, which can be reduced with chemical treatment if necessary. More natural approaches include promoting predatory insects, aerating the water, and making sure the surface has lots of movement. Another option that uses a fair amount of water is filling 5-gallon (20-L) buckets with water to attract mosquitoes to lay their eggs. Emptying this water every five days (you can use it to water plants) prevents larvae from maturing. Features can also attract unwanted wildlife, like neighborhood cats, that can have negative effects on wildlife.

— Perennial and Intermittent Pond Installation

Installing a pond is a great way to turn an upland yard into a mini wetland mosaic while also providing important resources for local wildlife. Frogs, toads, and some salamanders enjoy ponds that have shallow areas, slope gently, and have plenty of hiding spots along the shore and under water. Common species usually reproduce

In a garden designed for flowers, this pond hosts non-native plants, has steep edges that trap wildlife, and includes mosquitofish (genus *Gambusia*) for insect control. Designs like this can be easily modified for wildlife by adding a stone or wooden ramp, planting natives, and providing substrates for aquatic insects, like dragonfly (infraorder Anisoptera) larvae, to shelter in.

in ponds of less than 200 gallons (760 L), but replicating natural breeding areas that should occur in the ecosystem is always best. Installing a pond liner with rocky areas provides amphibians with the water they need, but specific soils and substrates may be required by certain species, like Wood Frogs (*Lithobates sylvaticus*). After the pond is filled, adding robust plants, logs, and stones increases your chances of attracting local wildlife. Keep in mind that a small, cleared area along the nearest shore of the viewing point allows more animals to drink from the pond and improves your ability to observe pond activities from a distance. Deeper ponds are required for hosting turtles or for keeping various fish species. For example, Pond Sliders (*Trachemys scripta*) prefer ponds that reach 4 feet (1.2 m) deep and over 1,000 gallons (3,800 L).

Both perennial and intermittent ponds do best in garden landscapes when they are placed in areas with morning sun and late-afternoon shade. Locations with both sunlight and shade can include the eastern sides of buildings, the north to southeast edges of large trees, and under a trellis. Another option is to fully vegetate the pond with tall vegetation, like cattails and rushes native to the area. Sunlight is important for growing plants and promoting algae that various insect larvae feed on. However, the sun's rays also warm the water and can create inhospitable conditions, especially in shallow ponds. Shade prevents the water from getting too hot and helps keep the soil edges damp, which is important for mud-nesting animals like swallows and puddling butterflies. Installing ponds near a deciduous tree allows winter sun to warm the water and prevent freezing in warmer climates, but also requires seasonal leaf cleanup to keep the water and equipment in good shape. When planting under trees,

A full-sun wetland with cattails along shallow areas. The cattails provide shade and structure for the wildlife in and around these gardens in Tulsa, Oklahoma.

make sure the area is far enough away from main roots to not significantly harm the tree. Likewise, no matter where the installation occurs, follow local digging ordinances and have underground utilities marked prior to digging. Call local services to mark lines (811 is the national "Call Before You Dig" number in the United States).

Once you've chosen an area with good lighting, measure the space and mark an outline on the soil where the edges will be. Ponds that support amphibians should be at least 3.5 feet (1.1 m) wide and at least 1 foot deep (0.3 m). Larger water bodies attract and support greater diversity. Although natural wetlands tend to have smooth margins, garden ponds can be any shape you want, as long as edges have at least one spot with a gradual slope at the edge so animals can easily crawl out.

After the outline has been made, excavate soil to the desired depth. For ponds using fabric liners, create a trench around the pond outline 2 to 3 inches (5–7 cm) deep. The liner can be tucked into this trench and buried to prevent the material from coming loose. If the pond will have soils and substrate for vegetation to grow, a foot (30 cm) of soil is generally sufficient. Underwater pots are a great alternative, and they add three-dimensional structure to the water column. Make sure to include the soil depth in the excavation and when selecting a prefabricated pond liner to ensure that the water column is deep enough (from the substrate surface to the water surface) for the plants you want to grow. For example, the American Lotus (*Nelumbo lutea*) does best in water depths of 2.5 to 4 feet (0.75–1.2 m), while clover ferns (genus *Marsilea*) do better in 0 to 12 inches (0–30 cm) of water. When using fabric pond liners, pond edges should slope gradually from about 3 inches (8 cm) below the water surface to 2 inches (5 cm) above at least in one area. This allows animals to easily move in and out of the pond. Prefabricated shapes generally do not have these slopes, so you will need to add rock slabs or logs for animals to escape.

Both prefabricated shapes and pond liners should have a soft, sturdy layer of sand underneath for support. Make sure no rocks or sharp debris are in this supporting layer. An underlay fabric can be added as well to further protect free-form liners from being pierced. In areas with clay-rich soils, excavation and packing the soil may be sufficient to create standing water, but steep sides will collapse unless fortified by stones, logs, cement, plants, or fabric.

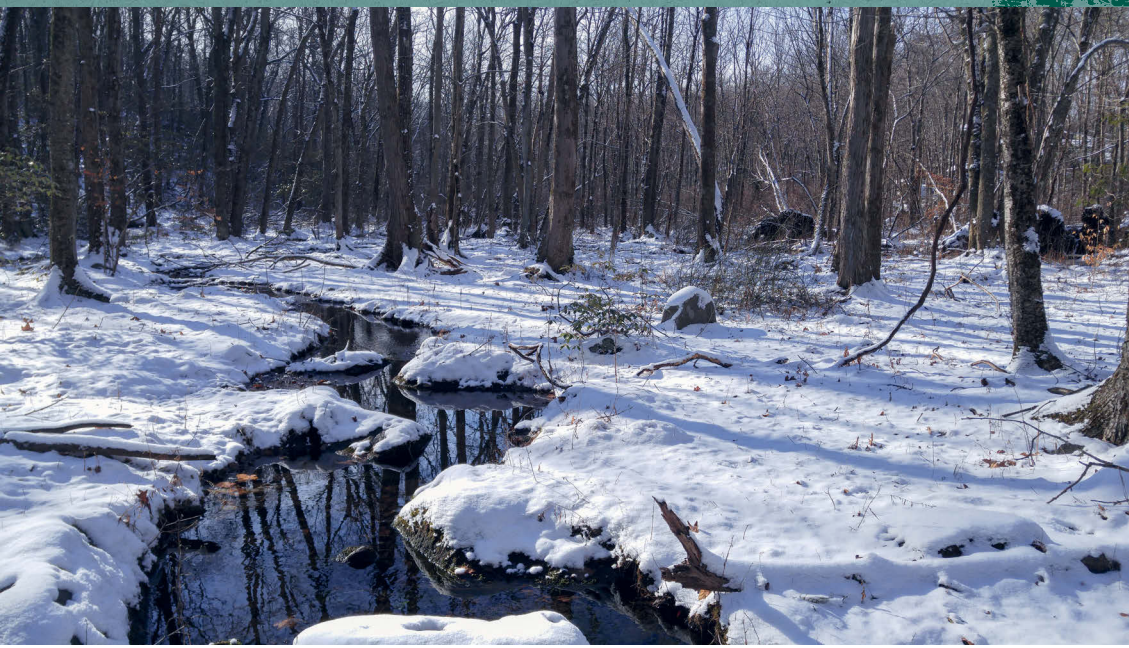
Place at least 6 inches (15 cm) of substrate in the deepest area of the pond, either against the liner or in a wide pot or other container. Washed sand and gravel look the cleanest at first compared to soil. However, as organic matter, dust, and soil enter the pond, all substrates darken. Cloudy water, caused by suspended particulates, is common in older ponds and ponds with soils. Filtration pumps and hay bales are best for pulling sediments out of the water column. Adding stones on top of the substrate builds structure into the water column, creating shelters and surfaces for animals to

A wildscape garden with both native and horticulturally developed plants and a pond. Notice the log placed in the prefabricated pond to help animals exit.

hide and hunt. Underwater caves, hollow logs, and vegetation also provide shelters for aquatic organisms. Similarly, hiding places—small caverns, rock piles, logs, mulch piles, dense plantings—should be installed near the pond as well.

For designs that include aquatic and emergent vegetation, adding plants should occur no sooner than a week after the pond is filled. This provides time for chemicals to neutralize and support any wildlife, like amphipods and native snails, that may come with the plants. Make sure plants are purchased from nurseries that do not have invasive species in their setups. Similarly, taking plants from a friend's pond can spread non-native biota.

Rainwater is the best option for filling ponds and fountains. When rain is not an option, you can usually fill the pond with tap water, but it is recommended to treat the water with dechlorinating powder; follow the manufacturer's instructions. If your water district uses longer-lasting chemicals, like chloramine, water will need to sit



An inspirational natural pool along a perennial stream in Westchester, New York, during winter. In colder regions, ponds may need heaters to keep water available to wildlife.

for a week or two before invertebrates can be safely added. Seasonal ponds should be allowed to dry out during dry seasons. However, in drought years, if amphibian larvae are not grown, supplemental, clean water may need to be added to prolong the life of the pond by a week or two. Small volumes of untreated tap water often make it into ponds from irrigation, but it is best to treat the water in a separate container before adding.

A freshwater isopod (order Isopoda) on pine needles in an emergent wetland of Louisiana. Aquatic invertebrates are common hitchhikers on purchased plants and are eaten by predacious insect larvae.

Aerating ponds with pumps, waterfalls, and spouts helps oxygenate the water, prevent mosquitoes, and improve the overall habitat for most species. Pumps should always be housed in a space that prevents animals from getting stuck in the intake point as well as prevents detritus from clogging the hardware. Keep in mind that vernal pool species, like fairy shrimp, toad tadpoles, and ostracods (seed shrimp), usually do not tolerate too much water movement. Using low-velocity pumps, dispersing water flow (say, using a spray fountain instead of a waterfall), or designing areas with low water movement will drastically improve habitat for these animals as well. Designing ponds and water features with the needs of target wildlife in mind is key to making the most beneficial habitat. This will likely require detailed conversations with professionals if they are hired to do pond installations, because many professionals are focused primarily on aesthetics or non-native animals like koi.

Replicating Absent Grazers

Urban environments are not suited for most large, native herbivores, which are important to wild, naturally occurring plant communities. It would be harmful to both the large herbivores and the urban or suburban landscape to try to facilitate their populations in gardens, so it is best to try to emulate animal impacts and natural patterns. Replicating damage to plants opens up areas for smaller wildlife to fly, promotes new growth, and reduces plant-on-plant competition. Actions that replicate larger animal disturbances on vegetation communities include removing and compressing herbaceous plant material, pruning shrubs, clearing snow, and thinning woody plants. When we mimic these activities, plants in our gardens will be healthier and provide more protein-rich forage for insects and small herbivores, nutrient cycles will better match natural patterns, and overall habitats will be more robust.

An overgrown urban area illustrates how plant communities can grow without herbivores. This area is too dense for humans to navigate, but small mammals and insects are able to maneuver through the growth. Notice a lack of browse lines and trails that would occur if bison, elk, bears, and humans were regularly traversing the space.

— Mowing

In urban and rural environments alike, mowing is an essential tool for managing herbaceous communities, keeping paths and borders clear, controlling non-native plant populations, and suppressing encroachment by woody plants. Mowing also replicates some of the natural processes that are mediated by once-abundant large animals. Bison, Elk, and deer are just a few of the large animal species that trample plants, reduce woody-plant abundance, and remove aerial vegetation, which allows sunlight to reach the ground and promote new growth. Grazing animals also cut through stems, which provides access points for many stem-nesting insects. In the absence of these animals, we have to rely on machinery to facilitate these important processes as well as control non-native plants. Even though mowing is crucial and mimics many of the overall effects of herbivores on plants, the act itself can be quite harmful to wildlife. Blade height, mowing pattern, seasonal timing, and frequency can all be adjusted to reduce harm to wildlife and reach desired management goals.

A late-fall mow of a herbaceous plant community prevents woody encroachment. This often leads to a small edge of shrubs, then wooded areas, as seen here.

A maintained path through a restored prairie in Baton Rouge, Louisiana. Paths here are a minimum of two mower widths for ease of walking. Planned paths should be a minimum of a mower width for ease of maintenance.

Short blade heights should only be used when mowing borders, paths, and lawn-like areas. Most lawn mowers for small areas have adjustable decks or blades that can be set between 1 inch (2.5 cm) and 4 inches (10 cm). Many lawn companies recommend mowing plants to 1 inch, a height that promotes stoloniferous grasses (those that spread via horizontal stems) over other plants. Wildlife-friendly lawns should be 2 inches (5 cm) to 4 inches (10 cm) tall. A height of 2 to 4 inches promotes more plant species, has more three-dimensional structure, and conserves water by reducing evaporation. Paths, borders, and wildlife-friendly lawns should be mowed every two to four weeks to prevent wildlife from nesting.

The activity of animals and their ability to move away from mowers and string trimmers (such as Weedwackers) are heavily influenced by abiotic factors, especially for cold-blooded animals like amphibians and insects. Many conservation groups have published information stating that early morning is the best time to mow because fewer animals are active. However, morning low temperatures, dew, and humidity prevent insects from being able to fly or scurry away. These same conditions also support the hunting activities of various amphibians and arthropods that seek shelter in the hotter, drier periods of the day. To reduce mortality of amphibians, reptiles, insects, and other arthropods, it is better to mow on days that are warm and dry, a few hours after dew disappears to an hour before sunset. This is because flying insects then have dry wings, many animals that might hunt in wetter conditions are in their hideouts, cold-blooded animals are warmer and motile, and all of these active animals are able to react faster. For mowed areas near taller vegetation, you need to check the edges before using the mower to clear out slower, larger wildlife, like box turtles and toads, that are hunkering down in the border. An easy trick is to pull a push mower behind you through these areas while carefully looking for wildlife. Make sure to mow slowly to allow as many animals as possible to get to safety.

A garter snake suns itself on rocks near its shelter.

An intentional shelter resource that attracts wildlife. Similar stone stacks can be added to landscapes and provide refuge when disturbances like mowing occur.

For herbaceous plant communities that are mowed twice a year to once every other year to prevent the encroachment of woody species, the same guidelines apply for selecting the time of day that will protect as much wildlife as possible. As discussed in chapter 1, herbaceous plant communities naturally undergo various disturbances that reduce aerial vegetation. This includes being trampled, grazed, and even burned. For insects and wildlife living in this vegetation, these disturbances can be harmful. Mowing vegetation also harms wildlife residing in stems, but it is possible to reduce the potential for harm. Planning mows for warmer days during the last few weeks of winter, before plants start to emerge, can help disturbed insects find new shelter. Similarly, this time period avoids nesting birds, caterpillars, and reptiles, many of which are underground as they overwinter in protected areas. Furthermore, using a mower with a blade set 5 to 10 inches (13–25 cm) above the ground allows less mulching of the cut stems, allowing insect nests within cut stems to stay intact.

Mowing to Remove or Manage Plants

Mowing, an important activity in conservation, is used to prevent woody-plant encroachment, control overall plant growth, and manage invasive species. A common use of mowers in conservation cuts back unwanted plants before they produce seeds to stop them from spreading. Interrupting seed set requires mowing to occur after plants produce buds and before seeds mature, which is in the growing season. This is the same period of time when many wildlife, including box turtles, caterpillars, insect pollinators, nesting birds, and lizards, are also most active and thus at risk for injuries from mowing, so it is important to take precautions. Only small, targeted mowing (known as spot mowing) should occur in areas that are not mowed every two to

A heavily disturbed area was reseeded two months prior to this photo. Mowers and grubbers were used to remove the shrubland for a right-of-way, but poor execution of the revegetation management plan left bare ground.

four weeks, like lawns and pathways. Areas mowed more frequently also endanger animals, but they should be more visible. Walking areas first helps displace animals and affords the opportunity to move more sedentary species. Likewise, pulling a push mower so that the user walks over an area before the mower increases the probability of detecting animals so that they can be avoided or moved.

Although urban gardens typically have smaller garden beds that can be managed with hand pulling, there are times when large areas or long borders are seeded and planted to mimic wild meadows. Landscaped areas like this are easily managed post-seeding with spot mowing and string trimming, which should be utilized approximately four to six weeks after seedlings emerge in any area where invasive species are densely colonizing. For smaller spaces, hand weeding should be sufficient, but if you choose mowing, follow these simple rules. Spot mowing or weeding should be repeated as needed to keep undesired plant species from crowding or going to seed. Benchmarks for implementing spot mowing include waiting until an unwanted species reaches a height of around 12 to 18 inches (30–45 cm) or when non-native species begin flowering. If push or riding mowers are used, mower deck or blade height should be set at 5 to 8 inches (13–20 cm) and raised as perennial plantings mature if the area has native plants. This helps encourage the native plants while also preventing the unwanted species from spreading. When invasive plant populations are too dense, mow plants down as far as possible and reseed. Be aware that some infestations may require herbicide treatment or solarization before reseeding.

In the first few years after seeding an area, the plant community is more susceptible to non-native plants also establishing, so weeding and monthly monitoring is

A roadside in Texas hosts a wide variety of low-growing herbaceous plants. These roadsides are mowed every two to three months to prevent woody plant encroachment, reduce fire hazards, and increase visibility while maintaining high biodiversity.

important. However, after three to five years, perennial vegetation should be established, and there is less risk of unwanted plant growth, but it is still important to monitor the plant community each year to prevent any non-native establishment. Spot mowing should occur to target only specific areas of weed growth and to prevent woody species from encroaching.

Once vegetation is fully established, mowing can occur every other year between October and March and as needed based on monitoring. For larger plots that are only mowed to prevent woody encroachment, half of the area should be cut each year. This allows half of the area to stay intact, providing safe havens for animal populations. Modifying which areas are mowed each year also promotes diverse landscapes, allowing some areas to mature a few years between cuts, while others can be cut twice each year. A simple example is to mow the eastern half of an area in the first mow,

After a meadow was seeded in Bedford Hills, New York, many invasive plants established. Targeted mowing and tilling occurred to control the invasive plants and trigger the seed bank again. Notice that desired native plants were left standing.

then the southern half the next, followed by the western half, then the northern half. This pattern follows the best management practices of only cutting half of the area but provides double-cut areas each time, which promotes annuals and grasses and leaves areas standing for up to four mow cycles.

— Trampling: Compacting Aerial Vegetation

Many herbaceous plant communities historically experienced large animals, including humans, moving through and resting in areas, which facilitated a few important processes. Plants were bent and broken, with some vegetation pressed against the soil, an action often referred to as trampling. Rain and snow also assist in compressing the vegetation, with more weight accumulating on non-vertical growth and bent shoots. Vertical, undisturbed shoots often remain standing in winter adding to localized habitat diversity. During winter in snow-prone areas, seasonal microclimates form based on vegetation structure. Taller vegetation often forms protected areas where birds can get out of the wind and even forage. Insulated soils provide warmer and drier spaces under vegetation that some smaller wildlife like voles and rabbits (owl prey) utilize. In spring, seedlings and emerging perennials are more successful growing through the thinner layer of compressed vegetation compared to dense standing layers of old stems and leaves.

Because many developed landscapes lack larger animals, most herbaceous growth is left standing throughout the year. However, reducing aerial vegetation height and compacting it is crucial because those actions mimic important processes that various wildlife depend on. Gardeners can mimic trampling by trimming back old stems at least once a year and laying them around plants. This can also be done multiple times

American Bison (*Bison bison*) lying down in wallows and on vegetation. Compacted vegetation creates shorter distances for seedlings to grow to reach sunlight, provides cover to prevent evaporation, and protects the soil. Pruning, weeding, and mowing mimics natural pressures like the presence of bison.

a year and can include pulled plants. In summer, laid-down vegetation functions as a natural mulch, shading the soils below and increasing moisture. As the organic materials break down, nutrients are returned to the area, and microhabitats used by a variety of animals and fungi form. Insects, lizards, toads, and salamanders use this layer for shelter in summer, and a number of beetles, moths, butterflies, and flies pupate and overwinter in this layer.

In autumn or early winter, last year's senesced (dead) shoots can be trimmed back and added to laid-down vegetation and be broken, bent, and pushed over to allow snow and rain to accumulate on them. Make sure to leave some shoots standing, especially seed heads, to feed the birds and provide perches. Trimmed and bent vegetation laid on the ground provides insulation to the soil during winter and creates cover for animals scurrying along the surface. Bent and broken vegetation helps create open spaces above the ground, much like evergreen shrubs. Shrubs can also be cut to provide hollows that birds can access to escape the wind and cold. Additionally, walking over areas after a snowfall helps expose vegetation and soils that many winter birds need access to for finding food. Through these actions, dramatic winter landscapes will be created with an abundance of texture and structure that attract wildlife.

Understandably, many gardeners do not want to trample the plants they have worked so hard to grow. However, by re-creating these microhabitats, many more species of wildlife can carry out their life cycles, and plants can grow back stronger in spring. Incorporating these techniques does not mean the entire garden must be affected; actions can be restricted to a small area and still provide many benefits.

An example of native vegetation halfway through winter. Isolated bunchgrasses and some other plants remain standing, while most vegetation has been laid over by wind and deer herds. Pruning and cleaning up dry vegetation is important in wildlife gardens. Trimmings can be laid around plants for natural mulch. This mimics natural processes of larger animals that are often absent in neighborhoods.

—Trimming and Pruning Softwood and Herbaceous Plants

Dried plant stems from various herbaceous and softwood plants are important for nesting native bees, wasps, and other insects. Common native plants that are used in gardens, such as Joe-Pye weeds (genus *Eutrochium*), elderberries (genus *Sambucus*), milkweeds (genus *Asclepias*), sunflowers (genus *Helianthus*), and wild bergamots (genus *Monarda*), among many others, have hollow or pithy stems once they dry out. Bees and most other insects will not nest in actively growing stems, but there are a few exceptions. There are also species of insects that do live and feed inside living plant tissue, like gall-forming flies (including the families Cecidomyiidae and Tephritidae) and wasps (family Cynipidae), as well as leaf miners (many species of moths, flies, wasps, bees, ants, and beetles whose larvae live in and eat the leaf tissue of plants). Both dead and living stems are naturally broken by a wide range of factors. Some actions that break stems are absent from most gardens, like large herbivores feeding or big animals (including humans) moving around. Other events like hailstorms, heavy rains, and high winds snap and bend vegetation. All of these things can also harm or move vegetation that contains nests, which animal life cycles and reproductive strategies must account for.

Plants in suburban and urban areas present new challenges not found in nature. Plant species that grow and die back without being grazed or broken cannot be utilized by cavity-nesting insects that rely on cut or broken stems for entrances. Vegetation in developed areas tends to be removed and shipped to local dumps and burned in burn piles. Both of these problems decrease the reproductive success of stem-nesting animals.

Due to the absence of some stem-breaking forces, it is important to trim plants so that insects can access the pithy centers and hollow areas. Diversifying the height

A wildflower-rich roadside near Gatesville, Texas, maintained by mowing. The lack of large animals is noticeable by the absence of trails, broken stems, and structural diversity.

of cuts provides more options for stem-nesting insects. Once stems are cut, insects like native bees can nest in the exposed hollows, but many species only use dry stems. Stem nests can take a full year to mature. This means that cut stems should remain in the landscape for at least a year or two to help insect populations. If further trimming is needed, cut the stems with clippers instead of mowers or hedge trimmers. Keep the stems on the property either on the ground as mulch or in a pile to allow insects to mature and emerge.

In wild areas, vegetation structure diversifies over time, leading to some plants with old stems and seed heads left standing, while others are broken and lie flat on the ground. During yardwork, you can replicate diverse vegetation structures by leaving some of the branches and seed heads intact, while trimming others back. Grasses, irises, yuccas, and many members of the sunflower family add vertical structure and texture to winter landscapes as well as provide food for birds and other wildlife. In the following year, empty seed heads with cavities and hollow stems will be used by insects, including native bees for temporary shelter during rains, cold spells, and even high winds.

For areas that have freezes, pruning and trimming back dead foliage should happen between December and a month before the last freeze. For warmer climates, trim and prune in the coldest weeks of the year, preferably when daytime temperatures are below 50°F (10°C). For plants with hollow or pithy stems, cut the stems back to between 9 inches (23 cm) and 18 inches (45 cm) tall, using a sharp tool to ensure a clean cut. Bunchgrasses should be trimmed to about one-third of their height; this helps with supporting future growth as well as providing resources for wildlife. The trimmed organic material can be placed around the plants to make a natural mulch

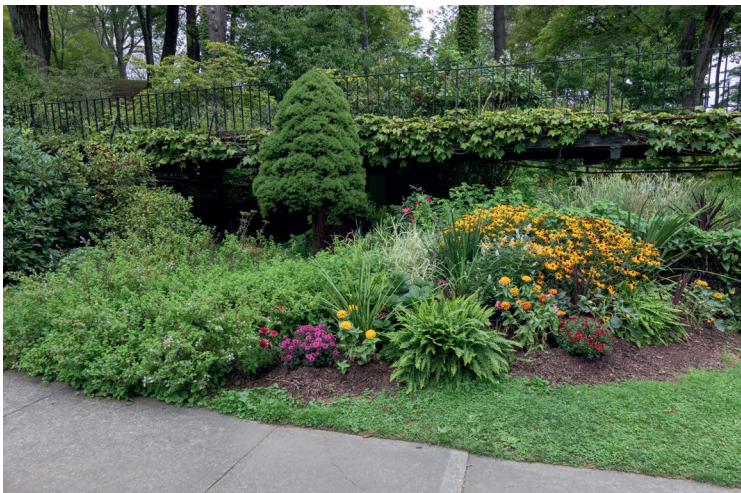
An overview of a grassy area in winter, with snow covering leaf litter and pressing some vegetation down. In spring, in healthy herbaceous habitats, most dead stems are pressed to the ground by snow, wind, and large animals. Leaning plants over before snow storms creates sheltered spaces under the vegetation.

Two male bees from different species take refuge in an iris seedpod during a cold rain. Leaving some vegetation standing for long periods is important for wildlife.

layer, which also allows any insect nests to survive into the following year. Another option is to tuck the trimmed vegetation under bushes or on the slow-compost pile—anywhere, really—but do keep the material in your yard to keep wildlife safe.

Shrubs That Tolerate Moderate to Heavy Trimming

Creating attractive landscape designs most often includes layering and structuring areas with plants. In many cases, shrubs are used to add medium height, color, and texture in a way that requires shaping. Fortunately, many shrubs that are preferred foods of various herbivores are accustomed to being browsed, making them tolerant of trimming and shaping. Below is a list of native shrubs that are great for making habitat and are good substitutes for horticultural plants like boxwoods (genus *Buxus*), privets (genus *Ligustrum*), and yews (genus *Taxus*). Make sure to check local native plant lists to see which species are native to your area.



Landscaping in a local park, in Oklahoma, using some native plants and common non-natives in an effort to support pollinators.

On a very localized scale, microclimates can be seen on minor features like bison patties, which provide nutrients, shelter, thermal insulation that affects water availability, and food resources for a variety of insects and fungi.

SHRUBS THAT TOLERATE MODERATE TO HEAVY TRIMMING

Agarita (*Berberis trifoliata*)

Baja Spurge (*Euphorbia xanti*)

Beaked Hazelnut (*Corylus cornuta*)

Big Saltbush or Quailbush (*Atriplex lentiformis*)

Black Sage (*Salvia melifera*)

Black or Twinberry Honeysuckle (*Lonicera involucrata*)

Brooms (genus *Baccharis*)

Buckthorns (genus *Ceanothus*)

California Coffeeberry (*Frangula californica*, formerly *Rhamnus californica*)

Catalina Cherry (*Prunus lyonii*)

Coast Live Oak (*Quercus agrifolia*)

Golden Currant (*Ribes aureum*)

Incense Cedars (genus *Calocedrus*)

Inkberry Holly or Gallberry (*Ilex glabra*)

Jojoba (*Simmondsia chinensis*)

Junipers (genus *Juniperus*)

Laurel Sumac (*Malosma laurina*)

Lemonade Berry (*Rhus integrifolia*)

Pacific Wax Myrtle or California Bayberry (*Myrica californica*)

Texas Sage (*Leucophyllum frutescens*)

Toyon or California Holly (*Heteromeles arbutifolia*)

Sugar Bush or Sugar Sumac (*Rhus ovata*)

Vine Hill Manzanita (*Arctostaphylos densiflora*)

Western Redcedar (*Thuja plicata*)

Yaupon Holly (*Ilex vomitoria*)

— Fertilizers and Nutrient Cycles

Although native plants do not need to be fertilized at the same rates that many cultivated landscaping plants and crops require, they do need nutrients. Natural nutrient cycles are complex and include decay, digestion, and non-organic chemical reactions. Native nutrient cycles can be encouraged without the use of synthetic fertilizers.

For example, to replicate the nutrient cycles and healthy soils that American Bison facilitated, gardeners can either place a few short piles of cow manure near plants to break down or spread a thin layer throughout plant beds once a year to every three years. Most urban gardens lack the insects that primarily facilitated the integration of bison manure into soils, like tumblebugs and dung beetles (family Scarabaeidae), but there are likely many arthropods and worms present in urban areas that will get the job done. Once manure is applied, make sure it has solid connection with the soil, and check on it in two to three weeks to make sure it is breaking down. Adding manure right before rains can help, but make sure the water is captured in the garden and not washing everything away or polluting local waterways. If the manure is not breaking down, it likely needs to be covered with dead vegetation and watered to attract decomposers and encourage fungi.

Habitats that have, or are regularly adjacent to, deciduous trees benefit from nutrient cycles fed by decaying leaves. Placing thin layers of leaf mulch around plants in fall and leaving them in place mimics natural processes and creates key microhabitats. If leaf mulch seems too messy, spreading fresh compost soils around garden beds will provide necessary nutrients. Similarly, nutrient tea made from leaves or compost can be used to water garden beds in spring and early summer to fertilize plants.

Locally sourced wood chips can be used to mulch garden beds, but these should not be left in place as their breakdown utilizes soil nitrogen. However, a light sprinkling (pieces should be spaced out and not overlap) of wood chips around mowed areas and early succession habitats every few years can revitalize soils. This method encourages soil microbiota and fungi that would naturally occur in the habitat, breaking down old wood from the trees that should be growing there and returning the nutrients to the soils without using up all of the soil nitrogen. Similarly, native

Deciduous leaves line the forest floor. Seasonal leaf drop feeds nutrient cycles and builds soils, both in the forest and in nearby habitats. Allowing leaves to remain in garden beds mimics this natural process. See "Leave the Leaves" in chapter 4.

MANURE

Animals of all sizes play key roles in local nutrient cycles, especially through digestion and defecation. In gardens, aged manure is regularly used to help improve soil nutrients and boost plant health. Naturally and historically, the abundance of large megafauna had similar effects. However, feces from small animals are also responsible for soil-nutrient changes. Research investigating plant growth along with nutrient content and respiration of soils, with and without spiders in the system, shows significant improvements when spiders are present. This work focused on two species: a web builder (a Southern Black Widow, *Latrodectus mactans*) and a wandering wolf spider (Carolina Wolf Spider, *Hogna carolinensis*). Soils under black widows had more ammonia and phosphorus, and wolf spiders were found to affect the composition of the microbial community. Other invertebrates likely have similar roles, and application of pesticides that harm arthropods interrupts these cycles. Work like this illustrates the importance of biodiversity and how the loss of biodiversity and abundance can have cascading effects.

A wolf spider (genus *Hogna*) moving across the ground. These spiders are important predators in gardens; new research shows they facilitate nutrient cycles.

nitrogen-fixing plants should be incorporated into landscape design to improve nutrient cycles and soil health.

— Removing Snow

After decent snowfalls, folks often clean snow from impervious surfaces for safety and easy walking. However, rarely do people intentionally clear snow away from

Two Moose (*Alces alces*) forage in snow, clearing trails and exposing soils, which creates foraging areas for other wildlife. Clearing snow in gardens is important for birds and mimics large animals moving through snowbanks.

pervious areas, especially gardens. Historically, humans and other large animals moving through the landscape or foraging actively compacted and removed snow, which exposed soils, seed banks, and vegetation. These actions created foraging areas for seed eaters, helped cool the ground further, and exposed cavities in snowbanks where birds could take refuge.

Clearing snow from areas around mowed areas, forest edges, and shrubs provides forage areas for birds, squirrels, rabbits, and other animals that are active in the winter. Similarly, sprinkling birdseed or providing seed feeders during winter can encourage local winter-bird populations. Walking through the snow on paths and across mowed areas creates spaces that smaller animals can use for movement and windbreaks for animals to shelter in.

— Disturbing Areas

Re-creating disturbances that larger, extirpated animals typically made can improve soil quality, shelter, and hunting opportunities for wildlife. Occasionally raking areas where organic materials like mulch and leaves are laid out replicates skunks and other animals rooting around while also facilitating organic matter breakdown. This can also help expose some of the soil invertebrates for birds to forage on that would naturally follow larger animals as they rooted around. Overturning soils between plants and pulling up weeds and leaving the roots facing the sky also exposes soil invertebrates for birds to prey on, while creating new food resources for soil invertebrates that break down organic materials. Regularly lifting and repositioning logs, pots, and other objects sitting on soil replicates foraging of larger wildlife like bears and badgers, prevents settling, and creates spaces for small animals to squeeze into

A Common Snapping Turtle (*Chelydra serpentina*) searching for a nesting location in a recently planted crop field in Louisiana. These turtles often use decaying stumps and mulch piles to lay their eggs.

for shelter. These spaces can also be provided by excavating soil pockets under objects and slightly elevating objects on small stones or planter feet.

Replicating Absent Predators

— Fences and Barriers

Large predators in a landscape can keep herbivores alert and out of areas where they do not feel safe. In ecology and conservation circles, this is called a fear landscape. As larger herbivores avoid specific areas, plants are able to establish and mature. Similarly, healthy predator populations suppress herbivore numbers, which also allows plants to grow and not be overbrowsed. Developed areas often lack large predators and sometimes even have abundant herbivore populations, which leads to native plants being denuded, damaged, and killed. Enclosures made with fencing, guards, and other barriers are needed to prevent herbivores from killing plants. However,

If we grow food on land around our houses, we can improve food security and nutrition, and reduce our carbon footprint. The average piece of fresh produce in grocery stores travels more than 1,500 miles, which reduces its nutrient value and requires a tremendous amount of energy. Wildlife habitats and native plants can coexist with food gardens.

designs should allow plants to grow just beyond the protection so that wildlife can still feed. This means, for example, that shrubs that grow 3 feet (1.0 m) wide when mature should have barriers 2.5 feet (0.8 m) wide so the branches can grow through the edges, while the main body of the plant is kept safe.

Wildlife-Friendly Fences and Barriers

Fences don't always make good neighbors, especially when we're living with wildlife. In many circumstances, fences, walls, and other barriers are necessary to keep pets safe, protect plants, and prevent access to dangerous areas. Poorly designed barriers can be hazardous to wildlife. Dangerous designs can include barbed wire, tall chain link, metal panels, cinder blocks, sheer walls—really any material that prevents animal movement, provides risk of injury, or traps wildlife.

For landscapes where animals are encouraged to roam, fences should have at least 3 inches (7.5 cm) between the lowest board or wire and the ground. The top of the barrier should be low enough for deer to jump over. Taller exclosure designs should have climbable areas for Opossums, Raccoons, and other mid-size wildlife to crawl over or under. These features do not have to be present throughout the entire fence. Instead, areas of the barrier can have wildlife passages for target wildlife to use. For example, small openings can be created throughout the bottom of fences and walls for box turtles, toads, and lizards to pass through that still keep most sizes of dogs from escaping. These openings can be kept small to keep larger animals out when warranted. Similarly, tall fences can have low points where animals can jump over and should also have suitable landing areas on both sides.

Barriers should lack a few common characteristics. Both loose and tight wires along the bottom and top of fences create areas where animals can get stuck and subsequently die of exposure. For example, deer can catch their legs between top wires and the fence, becoming stuck or breaking a leg. Thin wires, including barbed wire,

A Savannah Sparrow (*Passerculus sandwichensis*) sits on a chain link fence. A chain link fence can be wildlife friendly when raised enough for smaller animals to pass under it. Otherwise, they are a difficult barrier that restricts the movement of anything that cannot fit through the chain links.

A Great Horned Owl (*Bubo virginianus*) met a gruesome end on a simple barb from which it was unable to escape. Wildlife face many dangers around human developments, including in areas we don't associate with developments, like pasturelands or boundary fences on preserves.

that run horizontally are dangerous for birds and fast-moving animals like rabbits and foxes. Barbed wire in general is dangerous for wildlife because the barbs can wound animals but also because small and lightweight animals can get caught on the barbs and be unable to get unstuck. This leaves the animals defenseless to predators and the elements, and ultimately results in their death.

Solid walls made of stone, brick, or cinder blocks are generally easy for lizards, squirrels, and small animals with claws to crawl over. Conversely, they can be effective barriers for less-agile animals like box turtles, toads, salamanders, and snakes.

A gorgeous native-plant garden bed raised well above paths and with sheer walls. Toads, grubs, and many other animals are unable to climb these structures and are left exposed to the elements if they are attracted to the area. Providing shelters at the base as well as access to the beds improves safety for all wildlife.

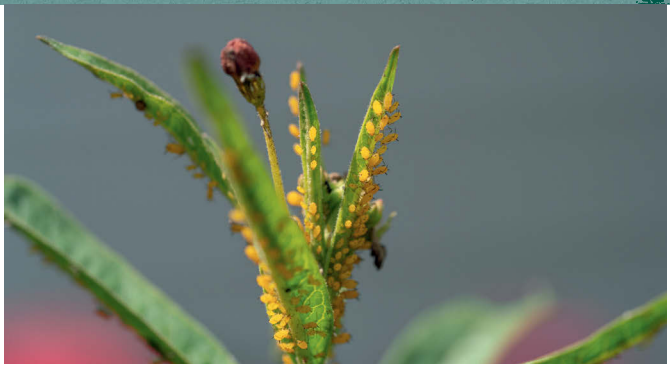
Part of a restoration project in Mamaroneck, New York. Native trees and shrubs were planted and protected from abundant deer herds. Cages were carefully placed to allow foliage to reach the edges for deer to feed on.

Making sure small spaces exist at ground level that these animals can fit through will help them move through their territories and set up homes in your landscape.

Protecting plants from overzealous herbivores and itchy animals that use plants as scratching posts is important for many gardeners. Galvanized wire cages can be secured close enough to plants so that their branches can grow and mature, while also allowing vegetation to grow through gaps and be browsed, feeding larger herbivores. Tree tubes also protect trunks from various wildlife, allowing them to grow above browse height. Making sure the cages are securely fastened to two or more anchor posts prevents deer and other animals from pushing the cages or tubes and damaging the growing plants. Both cages and tubes should be raised off the ground by at least 3 inches (7.5 cm) so that small animals can seek shelter as they see fit.

— Monitoring and Removing Organisms

In most suburban and urban landscapes, prey of extirpated large predators (wolves and cougars) cannot be removed without permits or licenses. However, some of the smaller prey species, like Raccoons, rabbits, and Groundhogs, can be removed by certified businesses. Developed areas also tend to have reduced populations or complete extirpation of smaller predators like raptors, foxes, Coyotes, and snakes. Their absence can lead to larger populations of their prey animals, including mice, rabbits, voles, and others. Smaller animals like invasive rats, flying squirrels, and skunks can also be managed by licensed companies. Without predators, prey populations can become problematic, which leads to habitat destruction, disease spread, and other problems, and using a reputable business to help manage their populations is good for the environment. However, ensuring that those companies are not using poisons like rodenticides is crucial. Animals that feed on the poisoned animals will also die. Owls, hawks, foxes, and even Mountain Lions have all been found dead with lethal



Oleander Aphids (*Aphis nerii*) cover the shoots of a Swamp Milkweed (*Asclepias incarnata*). Infestations generally attract predators, but sometimes intervention is needed to keep the plant healthy.

levels of rodenticides that they consumed by ingesting poisoned prey. Also see "Monitoring, Responding, or Letting Nature Take Its Course" in chapter 4.

— Calcium Bones and Antlers

Plants and animals rely on calcium for growth. Small, concentrated amounts of calcium are added into the ecosystem when the bones of carrion break down. Large antler-producing species, including White-tailed Deer (*Odocoileus virginianus*), Elk

ABOVE: A native Carolina Mantis (*Stagmomantis carolina*) crawls through the grass. These generalist predators are charismatic and adept at capturing insects, especially pollinators.

RIGHT: Deer, Elk, and Moose (family Cervidae) shed their antlers seasonally. These sheds are chewed on by a variety of small animals, including snails, as a calcium resource. Adding a shed or two to gardens can help local wildlife.

(*Cervus canadensis*), and Moose (*Alces alces*), drop their antlers annually, adding to calcium resources in the environment. A variety of animals, including field mice, squirrels, opossums, and foxes, chew on antlers and old bones to gain calcium. However, both carrion and antlers are often missing from our yards. In areas where supporting native mice and squirrels is an option, adding an antler near foraging areas

EXPLORATORY HABITAT GARDEN

The habitats we want to create are supposed to experience various types of disturbance, including localized changes brought on by foraging animals. As many sections of this book highlight, there are numerous species missing from our landscapes that facilitated disturbances that created key resources for other animals. Mimicking some of the disturbances caused by insectivores and mesopredators (animals that can be both predator and prey) can be fun for kids and adults, while improving habitat for select small species living in suburban areas.

Regular, small disturbances like logs and rocks overturned by foraging bears, hungry raccoons, scratching bison, and other extirpated species are easy to mimic. Incorporating those into a design takes a little more effort, however. A simple approach is to place sizable logs and rocks throughout the landscape in easily accessible locations. Then every few weeks, carefully lift the rock or roll the log, to expose the area beneath the structure, and gently place it back in the same area. Both adults and kids enjoy doing this, simply to see which animals are in the area. This simple action prevents objects from forming a tight interface with the soil and allows wildlife to continue to use the sheltering space. An additional step that keeps the microhabitat fresh is placing a few small twigs or

A Pileated Woodpecker (*Dryocopus pileatus*) sits on a fallen log while pulling it apart. Disturbances like this create new resources for animals to shelter and forage in. Recreating similar disturbances by lifting objects and putting them back or spreading small amounts of wood chips mimic important disturbances carried out by animals that are absent from our gardens.

will improve their health. For plants, calcium can be added to soils by sprinkling crushed eggshells, bone meal, or oyster shell, but make sure to do this at appropriate levels because calcium can change the soil pH.

Also see this chapter's section "Fertilizers and Nutrient Cycles" and the suet discussion in the chapter 3 section "Bird Feeders."

pebbles on the substrate before putting the structure back, which leaves a crawl space or microshelter for wildlife. These features are also great for engaging neighbors and friends with native habitat gardening.

Soil excavation by burrowing and wallowing animals creates areas that are used by some birds, like Savannah Sparrows (*Passerculus sandwichensis*), and other animals, like lizards, for hunting. There are a few different ways to mimic recently excavated soils. An active compost area or bin that is turned regularly mimics this habitat for many predatory species; prey species readily disperse when the compost is turned, which helps other animals find and consume them. Garden beds with mulch cover or leaf litter can be lightly turned in limited areas (i.e., not the full area) with a rake. Quite often, American Robins (*Turdus migratorius*) and towhees (genera *Pipilo* and *Melozone*) search these areas for exposed worms and grubs. As you weed, upturning pulled plants and leaving them in place or in a pile mimics the grubbing behaviors of animals like armadillos, Javalinas (aka Peccaries; family Tayassuidae), and skunks. Implementing this weeding practice also helps keep moisture in the soils and encourages natural nutrient cycles, as soil invertebrates feed on the upturned vegetation.

These disturbances should not be conducted across an entire area, but selecting a few spots every so often is very beneficial for wildlife. Depending on the types of animals and plants that may occur in the garden, wearing gloves and snake gaiters (protective leg coverings to shield against snakebites) and providing adult supervision will help prevent negative human–wildlife interactions.

A Canada Jay (*Perisoreus canadensis*) hunts along a soil cut near a road. Exposed soils naturally occur along streams, recent burrow excavations, and bison wallows.

PROFILES OF SELECT SPECIES

Conservation of areas sometimes focuses on protecting and providing habitat for one animal species; this is known as an umbrella approach. The idea is that by protecting the habitat of one species, all of the species that rely on the habitat are also protected. Although this tactic can have many positive impacts on the local ecosystem, research has shown that a multi-species approach is better, likely because more resources and habitats are managed, which increases overall biodiversity. Therefore, gardens that are designed to support the entire life cycle of multiple species also benefit more non-target species than a garden designed around one animal or one type of habitat. The following profiles work to promote specific species, but they can also be used to guide further research into local native wildlife not covered here.

The following sections focus on specific species and groups of species, including the networks they support, habitat requirements, and ways to make spaces more appealing. Most of these species do not occur throughout North America, but each profile illustrates the various considerations necessary to create robust habitat for the organism. No matter how much you may want a species to live in your garden, it is never acceptable to take wild animals from their homes and move them to your yard. Furthermore, it is often illegal to capture or transport wildlife without the proper permits. If an area in your garden or neighborhood is suitable for certain species, you can work with local rehabilitators and wildlife groups to utilize your yard for animal release. Even in situations where organisms may be in immediate danger, it is best to reach out to state and federal agencies as soon as possible to ensure that policies and laws are adhered to. For example, if an injured animal is rescued from a road, once the animal is out of danger, contact the proper groups to ensure it is taken care of

Umbrella conservation often focuses on creating habitat for a single species, usually a large species, like bears. The assumption is that by creating habitat for this one species that needs a lot of acreage, the habitat will support other wildlife. Data show this approach is much less effective than managing for multiple species.

A permitted biologist captures birds in a mist net for data collection and release. Nearly all birds in North America are protected under the Migratory Bird Treaty Act; harming or harassing them requires special training and permits.

and, if possible, released in a safe place. Too often, well-meaning folks try to care for animals when they have zero training, which can lead to malnutrition, disease spread, and even the death of the rescued animals.

Sometimes relocating an organism is necessary, but, again, it is important to make sure state and federal laws are adhered to. Furthermore, simply relocating an animal often leads to its demise. An animal released into an unknown space does not know where to find shelter, food, and water, and it may, as well, face territorial disputes with current residents. Experts and trained professionals will ensure animals are relocated into shelters, where they can take immediate refuge; having nearby resources drastically improves survivability. Similarly, some folks try to save plants and animals from

Urban landscapes regularly include barriers that prevent animal movement. Moving less agile animals from pavement into vegetation is mostly regarded as helpful to the animals. However, including access in designs is always best.

roadsides prior to bulldozer and mower maintenance. Although this is a noble effort, you need to contact local departments of transportation in advance to get permission and avoid possibly damaging underground utilities. Anytime a relocation occurs, it is also good practice to isolate organisms to prevent disease spread. This is especially true for aquatic organisms that can transport invasive species, fungal pathogens, and other diseases in waters and soils.

Native Plants

Native-plant communities are almost always removed from urban landscapes, even though they are important for most native wildlife species. Landscaping urban areas with native plants provides some animal species with appropriate forage, including: butterfly and moth larvae that specialize on specific plant species, native bees that prefer pollen and nectar from certain plant groups, and beetles, grasshoppers, slugs, and other herbivorous and omnivorous wildlife—all of which are integral for healthy food webs. Animals that are not provided for include specialists that feed on species absent from the designed plantings and fungus-feeding animals. Landscape designs that use native plants also reduce the amount of irrigation necessary to keep plants healthy because native plants are accustomed to the historical, local rainfall patterns.

Growing a diversity of native plants is important for supporting wildlife; however, it is also important to consider the landscape around gardens and created habitats. If only one garden is growing native plants, then growing an abundance of just a few species will provide sufficient forage for bees and butterflies that can forage on those plants. Conversely, if many households in the neighborhood are growing native plants, wildlife will be able to find forage in a variety of locations, so growing a more diverse yard helps increase the diversity of wildlife in the neighborhood. Since urban yards are limited to the amount of diversity they can support due to their small size, it is crucial to make sure the wildlife that are attracted have sufficient resources to be healthy. For bees, we currently do not have the data to develop minimum forage requirements for species, as we do for many game and agriculture species. It is clear that a single plant does not provide enough forage for bees (although it is usually sufficient for a caterpillar). Using the data that are available, targets can be estimated. Medium-size native bees typically forage no more than 150 feet (73 m) from their nest when ample floral resources are present, although they can forage up to 1,500 feet (730 m). If we assume, as a high estimate, that 10% of the wild vegetation is providing usable floral resources, a good target for flowering-plant cover is a minimum of 1,674 square feet (155 m^2) or a 40- by 40-foot garden (12 × 12 m).

TABLE 1 Native (and a Few Non-Native) Plant Species for Garden Use

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Red Maple	*Acer rubrum*	10	34	Tree. Full sun to part shade; tolerates sporadic inundation with water. Tolerates some trimming.
Maples	*Acer* spp.	25	59	Mostly deciduous trees that grow in full sun to part shade.
Common Yarrow	*Achillea millefolium*	86	2	Not a preferred host plant for any species, but Painted Lady (*Vanessa cardui*) and Salt Marsh Moth (*Estigmene acrea*) larvae feed on leaves. Flowers visited by many pollinators. Tolerates deadheading, some trimming.
Anise Hyssop	*Agastache foeniculum*	47	2	Perennial forb that grows in full sun to part shade. Prolific bloomer; attracts many pollinators; is deer resistant. Tolerates some trimming.
White Snakeroot	*Ageratina altissima*	4	5	Part-sun to sun-loving herbaceous perennial can reach 5 feet (1.6 m) tall. Prefers damp soils; produces white blooms in fall. Does not tolerate much trimming.
Wild onions	*Allium* spp.	5	1	Perennial bulbs with nectar-producing flowers. Visited by some bees, many pollinating flies and beetles. Great for borders.
Alders	*Alnus* spp.	3	583	Small trees that can form thickets and prefer wet areas. Wind pollinated, but vegetation supports many insects. Great for adding texture and structure to native gardens. Tolerates trimming.
Leadplant	*Amorpha canescens*	74	22	Full-sun to part-shade, drought-tolerant perennial forb that grows to 4 feet (1.2 m) tall. Spikes of dark purple flowers are produced June through September; visited by many pollinators. Tolerates some trimming.
Milkweeds	*Asclepias* spp.	39	37	Perennial forbs with various growth forms. Flowers produce copious amounts of nectar and are visited by a range of pollinators. Many species wither after blooming but can regrow with trimming.
Paper Birch	*Betula papyrifera*	0	46	Short-lived, early-colonizing tree with colorful bark. Does not tolerate heat very well but is a wonderful addition to forest-edge gardens in the north. Tolerates trimming.

continued overleaf

TABLE 1 *continued*

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Birches	*Betula* spp.	0	48	Most species are short-lived, early forest-succession trees. Vegetation supports various butterflies and moths, plus other insects, including sawflies (suborder Symphyta) and aphids (family Aphididae). Tolerates some trimming.
Desert Marigold	*Baileya multiradiata*	58	2	Short-lived, clump-forming, arid perennial that produces large yellow flowers. Spreads readily from seed.
American Beautyberry	*Callicarpa americana*	3	3	Full- to part-sun perennial shrub with attractive flowers and berries. Many bird species eat the fruits. Tolerates trimming.
Pecan	*Carya illinoinensis*	1	44	Fast-growing, deciduous shade tree that produces edible nuts eaten by squirrels, birds, and deer. Requires seasonal cleanup when planted over pavement.
Hickories	*Carya* spp.	1	62	Generally large, deciduous, nut-producing trees; important for various wildlife. Plan for their mature size when placing them in landscapes.
Ceanothus	*Ceanothus* spp.	32	45	Most species are full-sun, robust, flowering shrubs that support numerous pollinators. These shrubs are nitrogen fixers. Most larger species tolerate heavy pruning.
Blue Mistflower	*Conoclinium coelestinum*	8	3	Perennial forb that tolerates frequent watering, wet soils; does best in part shade to full shade. Purple blooms appear in June through the first frost. Flowers regularly visited by butterflies and moths; attracts Queens (*Danaus gilippus*) and Monarchs (*D. plexippus*). Tolerates some trimming.
Palmleaf Mistflower	*Conoclinium dissectum*	7	3	Perennial herb that tolerates drought and can grow in full sun to dappled shade. Purple blooms in June through first freeze. Flowers regularly visited by butterflies and moths; attracts Queens (*Danaus gilippus*) and Monarchs (*D. plexippus*). Tolerates moderate trimming.
Red Osier Dogwood	*Cornus sericea*	32	62	Perennial shrub that prefers damp areas and produces deciduous foliage and bright red bark. Flowers visited by pollinators; fruits eaten by wildlife. Great for borders or focal points. Tolerates heavy pruning.

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Hawthorns	*Crataegus* spp.	16	39	Shrubs and trees; over 100 species in North America. Most species are deciduous; provide important forage for wildlife with leaves and winter fruits. Most species tolerate moderate trimming.
Chollas	*Cylindropuntia* spp.	14	3	Branching cacti that produce flowers and fruits. Few reports of pollinators, likely because it is hard to collect bees on these spiny plants. Tolerate trimming; readily root from broken branches.
Tree Cholla	*Cylindropuntia imbricata*	6	2	Branching cactus that grows about 4 feet (1.2 m) tall but can be much taller. Flowers are bright purple; fruits eaten by some birds in winter. Large range and cold tolerant.
Sacred Datura	*Datura wrightii*	6	1	Perennial forb with large white flowers. Hawkmoths regularly visit flowers.
Purple Coneflower	*Echinacea purpurea*	40	7	Perennial forb with many cultivars. Flowers attract many butterflies, moths, bumblebees, and beetles; birds feed on seeds. Plants tolerate trimming and deadheading.
False Daisy	*Eclipta prostrata*	5	0	Widespread but poorly studied annual to short-lived perennial. Great groundcover in wet, mucky to loamy soils that receive full or partial sun.
Rubber Rabbitbrush	*Ericameria nauseosa*	28	9	Shrubby, weedy perennial that grows in a wide range of soils. Tolerates moderate trimming.
Fleabanes	*Erigeron* spp.	189	6	Annual to perennial forbs found in many habitats. Flowers great for pollinators; plants can arrive on their own. Some species tolerate trimming.
California Buckwheat	*Eriogonum fasciculatum*	74	42	Evergreen shrub with dense blooms in summer. Plants tolerate deadheading, some pruning. Attracts pollinators.
Rattlesnake Master	*Eryngium yuccifolium*	17	6	Herbaceous perennial with distinct flowers that attract various insects; hosts a number of butterflies and moths. Prefers well-drained, upland soils. Tolerates mild pruning.
Western Wallflower	*Erysimum capitatum*	3	3	Biennial with various growth forms, likely in response to habitat. Colorful blooms and interesting fruits. Does not respond well to trimming.

continued overleaf

TABLE 1 *continued*

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Late Boneset	*Eupatorium serotinum*	1	2	Perennial forb with white flowers; supports various adult butterflies and moths. Tolerates light trimming; can be cut back halfway in winter.
Spotted Joe-Pye Weed	*Eutrochium maculatum*	9	5	Herbaceous perennial that prefers full sun to part shade and wet growing conditions. Stems range from totally purple to mottled green, producing copious pink-purple flower heads used by many pollinators in late summer.
Apache Plume	*Fallugia paradoxa*	6	3	Desert shrub with attractive flowers and seeds. Tolerates moderate pruning in winter.
Ashes	*Fraxinus* spp.	3	161	Medium-size to large trees host many herbivorous insect larvae. Flowers not regularly used by pollinators. Abundant seeds eaten by rodents, some birds.
Firewheel	*Gaillardia pulchella*	42	5	Annual to short-lived perennial forb that produces copious blooms through most of the growing season. (The native range is in question.)
Dakota Mock Vervain	*Glandularia bipinnatifida*	7	0	Poorly studied plant with low growth habit and purple flowers often visited by flies, butterflies, moths, and long-tongued bees.
Curly Cup Gumweed	*Grindelia squarrosa*	67	2	Full-sun, short-lived, tough perennial with copious yellow flowers that attract many pollinators. Birds eat the seeds; plants spread readily.
Sneezeweeds	*Helenium* spp.	7	2	Mostly perennials with low-growing to tall herbaceous growth habits. Flowers are conspicuous and visited by various pollinators.
Common Sunflower	*Helianthus annuum*	168	41	Great plant for generalist pollinators and a few pollen specialists.
Maximilian Sunflower	*Helianthus maximiliani*	22	3	Perennial sunflower that can grow well over 8 feet (2.6 m) tall and create small thickets.
Hairy Goldenaster	*Heterotheca villosa*	65	2	Perennial forb that stays under 2 feet (60 cm) tall. Tolerates drought but prefers moderate water and well-draining soils. Tolerates moderate pruning.

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Dotted Gayfeather	*Liatris punctata*	7	2	Perennial forb that does best in well-draining soils and full sun. Hummingbirds, bumblebees, butterflies, and moths are common visitors to blooms. Tolerates trimming after blooms wither.
Lupines	*Lupinus* spp.	25	37	Large genus with annual and perennial species. Flowers visited by a wide variety of pollinators. Foliage often supports butterfly and moth larvae.
Silvery Lupine	*Lupinus argenteus*	16	6	Perennial, low-growing forb that produces pale purple flowers in late summer. Moderate pruning is tolerated.
Tahoka Daisy	*Machaeranthera tanacetifolia*	15	3	Low-growing, drought-tolerant annual that produces flowers throughout the growing season. Plants can grow up to 3 feet (1 m) wide. Tolerates moderate trimming.
Common Apple	*Malus pumila*	30	254	Fruiting tree that produces pollinator-friendly blooms in early spring. Many varieties exist; are great for wildlife and humans to eat. Extensive pruning is usually tolerated.
Apples	*Malus* spp.	56	348	A few native species occur in North America. All produce flowers visited by pollinators; can support a diversity of herbivorous insects. Moderate trimming is tolerated.
Turk's Cap	*Malvaviscus arboreus*	4	3	Perennial forb readily available in the horticultural industry. Pollination ecology poorly documented, but hummingbirds (family Trochilidae) often visit flowers.
Sweet Yellow Clover	*Melilotus officinalis*	161	33	Widespread, full-sun- to part-shade-loving invasive; common in urban areas; many insects use it for forage. Do not introduce it to new areas, but it can be a great addition to degraded soils in urban environments. Tolerates moderate trimming and close neighbors.
Seep Monkeyflower	*Mimulus guttatus*	9	5	Part-shade, wet-area perennial; a great addition to gardens. Flowers are likely visited by a diversity of pollinators. Plants tolerate some minor trimming.

continued overleaf

TABLE 1 *continued*

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Wild Bergamot	*Monarda fistulosa*	90	9	Tolerant of many growing conditions but does best in full sun and damp soils. Does well with neighboring plants; produces flowers throughout the growing season. Tolerates moderate trimming.
Honey Mesquite	*Neltuma glandulosa* (*Prosopodis glandulosa*)	61	37	Deciduous native shrub or tree that changes growth form depending on water received. Expanding in range due to agricultural practices. Flowers visited by many pollinator species; supports a wide variety of herbivorous insects. Moderate pruning is tolerated.
Common Evening-primrose	*Oenothera biennis*	7	16	Biennial plant with tall growth. Flowers regularly visited by hawkmoths (family Sphingidae). Plants do well with neighbors, readily reseed. Light pruning tolerated.
Clockweed	*Oenothera lindheimeri*	2	1	Abundantly cultivated in the horticultural trade, with few insect observations reported. But butterflies, moths, flies, and bees have been seen visiting flowers.
Showy Evening Primrose	*Oenothera speciosa*	3	1	Low-growing, vigorous-seeding perennial forb that is drought tolerant. Flower size changes based on water availability. Blooms all growing season.
Prickly pears	*Opuntia* spp.	137	27	Species-rich genus of perennial cactus native throughout most of North America. Plants are easily propagated from pads; flowers are visited by mostly bees, beetles, and flies. Great for pots or in ground; tolerates moderate trimming.
Texas Prickly Pear	*Opuntia engelmannii*	34	2	Widespread, medium-size cactus with variable petal colors, magenta fruits. Many wildlife, including birds, foxes, and insects, eat fruits. Plants tolerate some pruning and drought conditions.
Beardtongues	*Penstemons* spp.	210	33	Group of herbaceous, mostly perennial plants with showy flowers. Great forage for pollinators; host plants for a few butterflies and moths. Some plants, especially prolific bloomers, tolerate moderate trimming.
American Pokeweed	*Phytolacca americana*	12	2	Tall herbaceous plant with hollow stems, flowers that support pollinators, fruits for birds. Tolerates trimming and topping.

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Pines	*Pinus* spp.	0	399	Host plants for a number of insects; dead wood is used by some cavity-nesting bees. Great for shade and tolerate trimming.
Marsh Fleabane	*Pluchea odorata*	7	8	Wetland-loving, herbaceous annual plant with purple flowers that support various pollinators. Seeds are small, have unknown use by birds. Tolerates some trimming.
Redwhisker Clammyweed	*Polanisia dodecandra*	4	2	Medium-height herbaceous annual with large flowers. Supports many pollinators. Does best in sandy, well-draining soils. Does not tolerate pruning.
Poplars, cottonwoods, and aspens	*Populus* spp.	*2*	85	Medium-size to giant deciduous trees that support various insects. Flowers are produced in spring, likely do not support many pollinators. Create important habitat structure and tolerate pruning.
Trembling Aspen	*Populus tremuloides*	1	65	Deciduous, medium-size tree with beautiful fall foliage and colorful stems; supports a wide array of insects. Plants tolerate moderate trimming.
Common Selfheal	*Prunella vulgaris*	11	2	Regular occupant of mowed areas; naturally occurs in moderately moist, herbaceous plant communities. Perennial; produces copious flowers, supports various pollinators.
Black Cherry	*Prunus serotina*	16	54	Tall tree with small white flowers that support a myriad of bees and pollinators. Fruits are important forage for many animals, including birds.
Plums and cherries	*Prunus* spp.	226	109	Shrubs to tall trees that support various insects as host plants and flower producers. Fruits important for wildlife.
Douglas Fir	*Pseudotsuga menziesii*	0	40	Evergreen conifer that does not support pollinators but is host plant for various insects. Mature trees create important nesting resources.
Oaks	*Quercus* spp.	22	804	Keystone plants that support over a thousand insect species. Nuts are important for various wildlife. Growth forms include shrubs to large trees, some evergreen. All species tolerate pruning.

continued overleaf

TABLE 1 *continued*

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Upright Prairie Coneflower	*Ratibida columnifera*	41	2	Short-lived, herbaceous perennial that does well in dry to moderately moist conditions. Conspicuous deep maroon to bright yellow flowers. Great for borders and mass plantings. Tolerates moderate trimming.
Currants	*Ribes* spp.	102	35	Woody shrubs with deciduous leaves. Flowers attract various pollinators; fruits support array of wildlife. Most species tolerate moderate pruning, making them great for hedgerows or centerpieces.
Roses	*Rosa* spp.	129	170	Woody to brambling shrubs with various growth patterns and showy flowers. Attract many pollinators and various insects; petals often selected by leafcutter bees (genus *Megachile*) for nest linings. Most species tolerate moderate trimming.
Black-eyed Susan	*Rudbeckia hirta*	105	16	Commonly available. Has showy flowers. Able to grow in a wide range of conditions. Tolerates some pruning and deadheading.
Coneflowers	*Rudbeckia* spp.	165	18	Have mostly large, dense leaf-growth with flower stalks above. Do best in dry, sunny locations. Support wide array of pollinators. Seeds are staple forage for migrating birds.
Willows	*Salix* spp.	318	677	Generally wet-loving trees along with some shrubby species. Flowers appear early in the spring and feed many early-emerging bee species. Mature trees can be found in drier areas where roots have found a water source.
Sages	*Salvia* spp.	144	17	Found in various habitats. Flowers support many pollinators, are generally very conspicuous.
Lyreleaf Sage	*Salvia lyrata*	3	12	Has one of the larger ranges for the genus and is an aggressive spreader. Colorful flowers and vegetation make it great for garden beds. Attracts hummingbirds and bees. Tolerates light trimming.
Carolina Horsenettle	*Solanum carolinense*	2	10	Agricultural noxious weed and aggressive perennial native that supports bumblebees (genus *Bombus*), is host plant for many caterpillars. Fruits can be eaten by birds. Pruning is tolerated; bounces back after mowing.

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Silverleaf Nightshade	*Solanum elaeagnifolium*	31	3	Common roadside plant and noxious weed in some states. Flowers visited by various native bees. Caterpillars of White-lined Sphinx moth (*Hyles lineata*) feed on the vegetation.
Goldenrods	*Solidago* spp.	312	148	Found in a range of habitats. Most species produce copious, attractive inflorescences that support pollinators. Some species, especially late-stage meadow occupants, can be aggressive and outcompete other plants. Most species tolerate moderate trimming.
Canada Goldenrod	*Solidago canadensis*	94	42	Late-stage meadow occupant that competes with establishing shrubs and trees. Control spread through weeding. Flowers support migrating Monarchs (*Danaus plexippus*) and myriad pollinators. Plants tolerate moderate trimming.
Globemallows	*Sphaeralcea* spp.	237	4	Perennial herbaceous to lightly woody shrubs that are most abundant in western half of North America. Some species stay very low, while others reach 4 feet (1.2 m) tall. Large, showy flowers attract various pollinators. Most species tolerate moderate trimming and shaping.
New England Aster	*Symphyotrichum novae-angliae*	8	6	Fall-blooming perennial. Important pollinator forage as well as support for various insects. Tolerates moderate pruning. Better for pollinators than grass, best used with other flowers
Dandelions	*Taraxacum* spp.	172	3	Non-native well established in urban and suburban environments. Plants do not invade areas without disturbance, are quickly outcompeted by native plants. Better for pollinators than grass; best used with other flowers.
Northern Highbush Blueberry	*Vaccinium corymbosum*	46	45	Medium-size shrub with dark green, deciduous foliage. Flowers good for pollinators; fruits support various wildlife. Mature plants tolerate moderate trimming.
Blueberries and cranberries	*Vaccinium* spp.	147	56	Small to medium-size shrubs with deciduous foliage. Flowers support pollinators; fruits support various wildlife. Mature plants usually tolerate moderate pruning.

continued overleaf

TABLE 1 *continued*

COMMON NAME	SCIENTIFIC NAME	BEE SPECIES THAT VISIT	BUTTERFLY AND MOTH LARVAE KNOWN TO USE IT AS A HOST	COMMENTS
Cowpen Daisy	*Verbesina encelioides*	90	10	Annual; conspicuous yellow flowers attract pollinators. Plants tolerate heavy pruning; can be shaped along borders or left in mass plantings.
Tall Ironweed	*Vernonia gigantea*	11	4	Late-season bloomers support many pollinators and insects. Birds eat seeds in winter. Can reach 10 feet (3 m) tall; tolerates some trimming.
Corn	*Zea mays*	2	49	Important plant for many herbivores, rodents, birds. Does not tolerate trimming.
Golden Alexander	*Zizia aurea*	70	3	Full-sun- to part-shade-loving, low-growing perennial; produces domes of yellow flowers in late spring, early summer. Does best in damp soils. Native host plant for Black Swallowtail butterflies (*Papilio polyxenes*).

In table 1, 90 plants that are mostly native to North America are presented, along with a few widespread non-native species that have been adopted by wildlife. Information includes the number of bee species and Lepidoptera larvae reported from the plants, along with key characteristics, including tolerance to trimming. Note that some plants do not support many bees or larval hosts, even though they might flower prolifically. These plants are still important to their ecosystems because they can provide shelter, forage for other pollinators not listed, and key resources for wildlife, but they should not be selected as forage for native bees. Conversely, many flowering species support hundreds of species of bees. To see if these plants might be a good choice for a specific area, look at local resources and species maps to see if they are

Rattlesnake master (genus *Eryngium*) is a gorgeous plant for full-sun areas. It adds unique texture and supports caterpillars and pollinators.

There are many goldenrod species (genus *Solidago*) across North America. Some are very aggressive, while others are hard to care for. All of the species provide copious blooms that attract a wide variety of pollinators.

Golden Currants (*Ribes aureum*) are beautiful native shrubs that tolerate trimming and produce flowers for pollinators and berries for birds.

Showy Evening Primrose (*Oenothera speciosa*) is a prolifically blooming, low-growing plant that readily spreads by seed. A large variety of pollinators visit these plants. Great for borders.

The caterpillar of a Cecropia Moth (*Hyalophora cecropia*) munches away on tree leaves. Planting native trees and other foliage plants that feed herbivores is crucial for a healthy habitat. Too much focus is often put on flowers for pollinators.

A Ruby-throated Hummingbird (*Archilochus colubris*) visits flowers of a bee balm (genus *Monarda*) species. This plant genus is great for gardens; it adds color and texture and is a favorite of pollinators.

American Beautyberry (*Callicarpa americana*) is a semi-shade-loving shrub that produces flowers for pollinators and berries for birds.

native to your area. Similarly, use local resources to find native plant lists and try to gather information on which wildlife are supported by those species.

Garden Insect Profiles

An incredible array of animals will quickly establish in native plant gardens, even more so when robust habitats are present. However, many resources ignore how to create habitats for non-pollinator arthropods. The following ten profiles discuss a variety of arthropods that are important to local food webs and have a range of habitat requirements. Some are excellent pollinators, while their larvae feed on other pollinating insects. There are also a few predators, like dragonflies, that help control insect populations (see chapter 2 section "Monitoring and Removing Organisms" and chapter 4 section "Monitoring, Responding, or Letting Nature Take Its Course" for managing populations). If there are specific insects not mentioned here that you would like to attract as residents, research where they lay their eggs, where they prefer to shelter, how and where they overwinter, and what they eat—then provide those resources.

— BEE FLIES

A bee mimic fly (genus *Bombylius*) and a leafcutter bee (family Megachilidae) nectar on a Cowpen Daisy (*Verbesina encelioides*).

Common flower visitors, bee flies (family Bombyliidae) hover at flowers while feeding with their long proboscises. Their larvae, however, are parasitoids, and each species feeds on specific groups of insects, including species that feed on ground-nesting bees. Adult bee flies that parasitize bees follow foraging females from flowers to their nest entrances. The bee fly then flicks her eggs into the nest entrance with her legs. The eggs hatch, and the larvae crawl through the nest until they find their host. In many cases, the fly larvae consume the pollen provisions first and then attach to the bee larvae to finish growing and eventually pupate, which kills the bee. Nest parasites luckily rarely infect the entire ground nest due to the way bees excavate, filling access tunnels of provisioned cells with soils excavated as they form new cells.

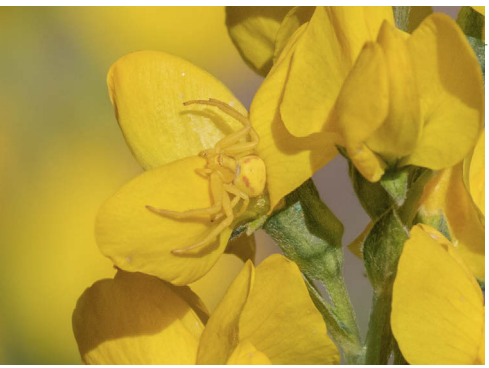
— BLISTER BEETLES

Most species of blister beetle (family Meloidea) have larvae that are ectoparasites of other insects. Unlike many other insects with parasitic larvae, blister beetles

A blister beetle (*Nemognatha nemorensis*) nectars on a yarrow flower.

lay their eggs away from nests, and the larvae have to find a way to their prey. Newly hatched larvae have well-developed legs and search for their host. For the species that feed on bees, the larva attaches to an adult bee and rides back to the nest. There are also species that search for nests of their prey on their own. Some blister beetle larvae can replicate host pheromones to attract male bees. They then use the males to get to the female bees, subsequently attaching to them, riding them back to their nest, and detaching once inside. After the larvae are inside the nest, they find a cell to develop in, killing the young bee. Some blister beetles destroy multiple bee cells in their development.

Blister beetles rarely become abundant enough to cause mass nest infestations. This is mostly due to their manner of using adults to get to nests. Free-roaming blister beetle larvae typically attack ground-nesting bees or wasps, while hitchhiking larvae, also called phoretic larvae, parasitize both stem nests and ground nests. In gardens where natural dynamics are missing, it is important to monitor bee hotels and ground-nesting areas to see if blister beetles are becoming a problem. Look for adult bees riddled with amber-colored hitchhikers as well as blister beetles emerging from nest sites. Take action to prevent more bees from nesting in these areas for a season to force the blister beetle populations to migrate. Take care when interacting with blister beetles because they excrete chemicals that can burn skin on contact.



A bright yellow morph of a flower crab spider (family Thomisidae) blending into the petals, ready to subdue pollinator prey.

— CRAB SPIDERS

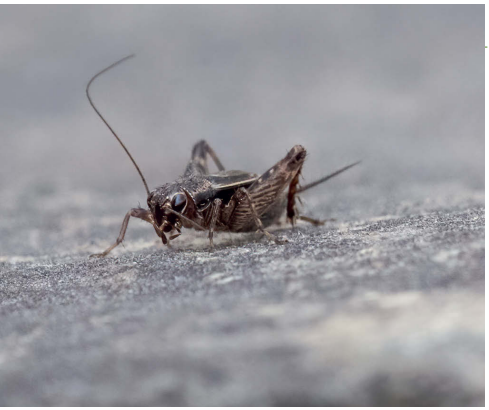
Two main groups of crab spiders (family Thomisidae) are found in gardens: the ones that sit on flowers, and the ones that live on or near the ground. Both types are ambush predators that can be easily identified by their location and coloration. Gardens with abundant flowers tend to attract flower crab spiders quickly as they regularly disperse via the wind. Conversely, ground crab spiders rarely disperse via the wind, but they are able to and can establish in good habitat. Both types of spiders are indicators of decent biodiversity.

ABOVE LEFT: A bumblebee (genus *Bombus*) worker falls prey to the ambush of a crab spider (family Thomisidae).

ABOVE RIGHT: A ground crab spider (genus *Xysticus*) crawling on stone. These spiders are often found around organic-rich soils and fallen logs, and sometimes on vegetation.

Flower crab spiders include several genera (*Mecaphesa*, *Misumena*, and *Misumessus*, among others) with bright coloration that allows them to blend into the flowers they perch on. Their taxonomy is muddy, and identification to species can be pretty tough without close-up photos of specific characteristics. Many species have the ability to change their coloration to camouflage themselves with floral colors or leaf colors. Their diets are broad, and they feed on insects opportunistically. Quite impressively, flower crab spiders are able to subdue insects much larger than themselves. These spiders crawl under flowers with their prey. If you are looking for them, search flower heads for hungry spiders or look for captured pollinators hanging from under flowers. Flower crab spiders are common in gardens with lots of blooms and abundant insects.

Ground crab spiders (genus *Xysticus*) are most commonly found in wooded habitats, crawling on logs, trees, leaf litter, and stones. Most species in this genus have cryptic coloration, with mottles of browns and black. Overall, their diets are broad and include mostly arthropods that they can subdue. Providing mulch, leaf litter, and dead wood in semi-damp to dry areas provides habitat for these cute spiders.



A cricket moves away from the protection of vegetation.

— CRICKETS

The soft sounds of crickets (family Gryllidae) chirping are essential for a summer-night soundtrack. However, many lawn and pesticide companies only see crickets as pests and promote ways to remove them from our landscapes. Although crickets can damage plants and eat clothing, promoting their populations in our yards helps build better habitats. In addition to their sweet serenades, crickets are food for many animals, including toads, birds, and lizards, plus they are important decomposers. Promoting crickets in a garden is fairly simple; however, some care is warranted.

Most species of crickets are omnivorous and consume both living and dead plant material, as well as other arthropods. Plants within their diet include lawn grasses, edible garden plants, and petals of many flowers. They also feed on mulch, cardboard, tree bark, and roots. When there is not enough preferred food, crickets will also munch away on wood siding, which makes a house more susceptible to leaks and water damage. Therefore, it is important to implement some control measures, including sealing gaps around windows and doors to prevent insects from entering your home. Similarly, when you design natural areas with key resources away from buildings, crickets will be attracted to those microclimates rather than entering homes.

Habitat for most ground-dwelling cricket species includes damp areas for refuge in both summer and winter, as well as food and places to lay their eggs. During the warmer months, crickets prefer damp, dark areas that they can quickly dart into when predators approach. These areas include small vegetation piles, like matted-down plants compressed by large mammals resting; dense stands of plants; small and large animal burrows; damp rock walls and crevices; and organic debris like wood, leaf litter, and mulch piles. Many species also begin singing for a mate in early summer, with some females able to lay a hundred eggs every few days. As autumn turns to winter and temperatures drop, crickets begin finding protected places to escape the cold. This includes inside houses, basements, and crawl spaces; however, areas in buildings typically do not have enough humidity, which leads to the crickets quickly perishing. In wild areas, overwintering species find refuge in a variety of habitats, including old tree-root systems, large logs breaking down, animal burrows, and vegetation piles.

Creating habitat for crickets in the garden can be done in a few steps. Most species have annual life cycles and overwinter as eggs or nymphs. Eggs are laid in soft soils,

A field cricket (genus *Gryllus*) that was hiding under garden-bed border stones. Providing pockets of mulch belowground and damp soils improves areas for crickets.

often under leaf litter, logs, or in dense vegetation. Hibernating areas for species that survive through winter can be replicated by installing a mulch pit below the frost line, which also serves as an egg-laying area. Designs are discussed in chapter 2. Creating summer habitat includes providing shelters to sing from, places to feed, and damp spaces to hide. These areas can be created by using large branches and tree trunks in garden designs, keeping old tree-root systems intact when trees need to be removed, using mulch, excavating burrows under large rocks, and leaving leaf litter. Sheltering areas with organic materials will also provide food for crickets, as will placing plant trimmings around plants. Fast- and slow-compost piles also attract crickets, as do cardboard and organic materials placed in any area that stays damp.

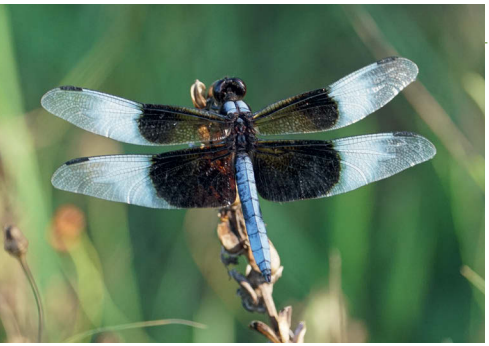
— CUCKOO WASPS

Across North America, brilliantly metallic colored cuckoo wasps (family Chrysididae) are often seen visiting flowers sipping nectar. Cuckoo wasps are external parasites that develop on the larvae of other insects, including bees. Many species are only about a tenth of an inch, or a few millimeters, in length, but some species have adults that grow to a quarter-inch, or roughly 8 millimeters, long. Adults search out nests of sawflies, wasps, bees, and ants to lay their eggs. When adults are not visiting flowers, they can be observed crawling around

Bee hotels have unnaturally high densities of hosts for Cuckoo Wasps.

A mature cuckoo wasp (family Chrysididae), which can be a parasitoid of a variety of arthropods.

the ground and along surfaces, hunting for nest entrances. The best way to promote these wasps is to keep mud nests from wasps intact and provide robust habitat for their prey, bees and wasps.



An adult dragonfly (infraorder Anisoptera) resting on a perch. Dragonflies often select flat surfaces in open areas for perches. Tall vegetation is used as well as adults search for prey and conserve energy.

— DRAGONFLIES

With nearly 400 species in North America, dragonflies (infraorder Anisoptera) are one of the most iconic groups of insects. Most folks do not realize that the adult forms for most species are short-lived compared to their aquatic larvae. Depending on the species, larval forms can take up to five years to develop or just a few months. Both larvae and adults are voracious predators and important in their ecosystems. Although many species are associated with wetlands, where they lay their eggs, grow up, and hunt, a number of species also have migratory adults. Migratory species are able to lay eggs in new ponds and wetlands as well as hunt in extremely dry climates, including deserts.

You can encourage dragonflies by installing a deep, perennial pond with vegetation and rocky bottoms for shelter. Larvae of larger species forage on small fish and tadpoles, as well as aquatic invertebrates. (Mosquitofish are hunted, but they can also take over a pond and consume everything that moves, so it is not a good idea to keep these fish.) Some species common in mountainous areas prefer moving water, and artificial creeks can be designed for them. For areas where a habitable water feature

is not feasible, providing ample prey habitat will attract hunting adults. Some dragonflies prefer to perch on twigs that stand above the nearby vegetation so they can rest while searching for food, while others are active fliers that capture food and rest in trees. Check out local resources for which dragonfly species occur in your area to better design habitat for them.

— FIREFLIES

Fireflies or lightning bugs (family Lampyridae) light up along the lawn. Larvae can spend a long time underground, so avoiding grub killers and lawn insecticides is crucial for their populations.

Fireflies (family Lampyridae) were once a common sight in the suburbs of eastern North America. However, with increased pesticide use, more spaces devoted to lawns, and an abundance of impervious surfaces, as well as overall habitat loss, fireflies are becoming rarer and rarer. For gardeners who enjoy seeing the glow of fireflies, creating habitat for them requires year-round shelter, prey species habitat, and protection from pesticides.

Fireflies are beetles, with an underground and terrestrial larval form. Almost all species are predatory, feeding on soft-bodied arthropods like slugs, grubs, and snails. Research on a firefly species in the genus *Phorus* showed that larvae prefer lightly damp, loose, loamy soils, where they spend the day underground and move to the surface using established tunnels at night. Although some disturbance to soils might be tolerated, it is best to leave areas where larvae develop undisturbed.

Leaf litter and objects on the surface of soils provide larval hunting grounds and tunneling locations. Areas like this can be under shrubs or tucked behind larger objects.

For some species, life cycles take one year, and for others, they can take two years. Creating safe sheltering spaces for larvae includes providing loose, loamy soil that is adjacent to hunting areas that provide habitat on the ground for small slug species, worms, grubs, and caterpillars. In the wild, these areas tend to include leaf litter, old logs, and edible plants for prey. In designed landscapes, this can be easily achieved by incorporating pesticide-free mulch and leaf litter around plants, and loose soils between plants and under rocks and logs, in an area that is naturally or artificially kept damp.

An Eastern Lubber Grasshopper (*Romalea microptera*) in Louisiana. Grasshoppers are important food sources for many animals, including baby birds.

— GRASSHOPPERS

Although grasshoppers (family Acrididae) and other leaf-eating insects are often considered pests, they are important food for birds, mammals, reptiles, amphibians, and predacious arthropods. There are migratory and non-migratory species, both of which can easily be attracted to landscapes. Most species feed on soft, herbaceous plant materials, including young grass leaves, deciduous leaves, flowers, and crop plants. Some species also regularly scavenge on other insects.

Promoting grasshopper populations is mostly done by planting native plants and reducing pesticide use. Ensuring that bare, soft ground is available for egg-laying females and that dense, dry vegetation is available near the ground in some areas will provide shelter for nymphs and adults alike.

— MOSQUITOES

Possibly one of the most despised insects in the world, mosquitoes (family Culicidae) can spread diseases and cause irritation, but they are an important part of the ecosystem. Mosquitoes are a type of fly. All flies have a complete-metamorphosis life cycle, where they hatch from eggs, develop through stages of instars as larvae, pupate, and metamorphose into adults. Due to their propensity to show up in wildlife gardens, wanting to reduce their populations is an understandable goal. However, suppressing their populations can be difficult due to their fast life cycle, small size, and ability to travel. Luckily, there are a few methods to suppress their populations that do not involve general pesticides.

Control measures focus either on the aquatic habitat where the eggs, larvae, and pupae develop or on adults. Biocontrols such as mosquitofish (genus *Gambusia*) have

Mosquito (family Culicidae) larvae in an errant bucket left in the garden. Some species can develop in less than a week, so dumping standing water or treating water with dunks is necessary to reduce mosquito populations.

A female mosquito (family Culicidae) unsuccessfully risking it all to get a blood meal so that she can lay eggs.

been introduced around North America with little success because these fish feed on everything they can catch. However, in wildlife gardens, mosquito-eating fish can be useful if ponds are not supporting amphibians or dragonflies. Aerating ponds with strong surface disturbance is another option. New products known as "dunks" use a form of botox from the group of bacteria called *Bacillus thuringiensis israelensis* (Bti). These dunks are stored as dry discs that, once placed in a body of water, affect aquatic fly larvae, especially mosquitoes, and do not directly harm other animals, including tadpoles. Many gardeners have installed mosquito buckets, which hold water and dunks and require cleaning every 10 to 14 days. A chemical-free design uses the same setup, with buckets and stagnant water that simply need to be dumped before larvae turn into pupae (roughly every 4 to 5 days). This method turns the mosquito

larvae into fertilizer and food for scavenging invertebrates. Adult-focused controls include CO_2 traps, which prevent further reproduction, and mosquito repellents to keep adults away. Cities and pest-control companies regularly encourage mosquito fogging; however, these chemicals kill all insects and should not be used.

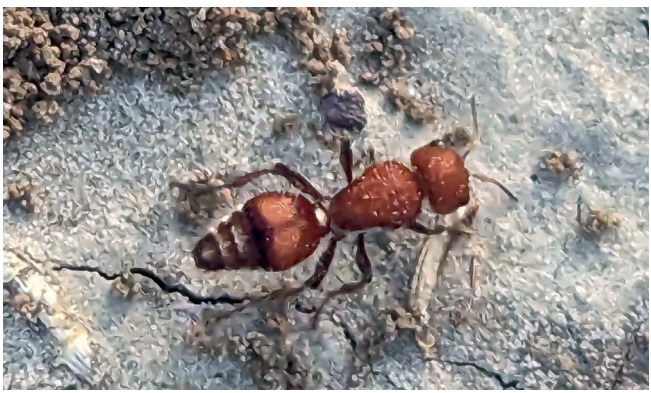
Both male and female mosquitoes feed on flower nectar and are regularly consumed by insect predators, like dragonflies, spiders, bats, ambush bugs, and some birds. Once wildlife ponds establish and begin to host decent biodiversity, mosquito populations should balance out, especially when surface-disturbing aeration like waterfalls are included in designs.

A Klug's Velvet Ant (*Dasymutilla klugii*) hunts for nests along a two-track road in Texas. Their larvae are parasitoids, but it is unknown which species they feed on.

— VELVET ANTS

Velvet ants (family Mutillidae), whose females lack wings and males can fly, are wasps that mimic true ants (family Formicidae). They are found throughout most of the United States, Mexico, and parts of southern Canada, with the highest diversity occurring in arid regions. Most species parasitize nests of other Hymenoptera, including sawflies, wasps, bees, and ants. The reports of bee-nest parasitism are mostly of ground-nesting bees, but they have also been found in nest blocks hung 3 feet (1 m) above the ground.

Most female velvet ants can deliver very painful stings when harassed. However, these parasitoids function as an important control of wasp populations. Their presence indicates decent biodiversity, but care is warranted when encouraging their presence.



A female velvet ant (*Dasymutilla scaevola*) scurries across sands in northern Texas, hunting for nests to parasitize.

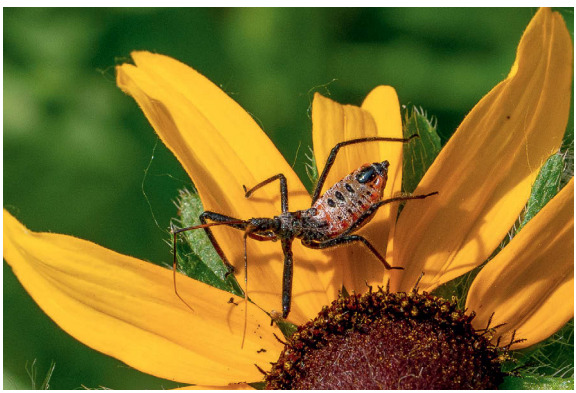
Key habitat aspects for most species include barren ground between plants, for other insects to nest in and velvet ants to hunt on. Adult velvet ants drink nectar, so providing low-growing, nectar-producing flowers helps support their populations.

— PREDATORY GARDEN INSECTS

A bumblebee-mimic robber fly (family Asilidae) feasts on a captured fly. These insects are generalist predators that feed on many species of other flying insects.

There is no great way to control any of the non-wasp predatory groups of arthropods because most of them are highly mobile and susceptible to chemicals that also kill the insects gardeners are trying to promote. This means that even removing predatory arthropods by hand will only produce temporary change, as more will arrive. Quicker recruitment of newcomers occurs when the area is filled with floral resources and food items (prey). Bees, butterflies, and many other insects have high predation rates naturally; this is why they produce high numbers of offspring. That said, if there is simply a year where there are just too many natural enemies, the best management strategy is to remove the blooms from plants. Without an abundance of flowers present, insect populations experience the natural process of changing habitats and are forced to migrate. In doing so, pollinators will have to forage somewhere else, as will their predators, which helps restore balance to the garden. After a week or two, plants can be left alone and allowed to flower again, recruiting pollinators to the garden once more.

There are a variety of ambush predators in the insect family Reduviidae, species that often feed on bees, perch on flowers and wait, then capture bees as they forage.



A young ambush predator bug (family Reduviidae) on a flower. Throughout their life cycle, these insects are voracious predators. Monitoring predator abundance is important. Our gardens lack many of the natural processes that regulate populations. See "Monitoring and Removing Organisms" in chapter 2 and "Monitoring, Responding, or Letting Nature Take Its Course" in chapter 4.

Generally, these insects do not become overly abundant, because most species have the ability to fly and do not appear to establish territories for long periods of time. Commonly seen Reduviidae predators are "bee assassin bugs" (genus *Apiomerus*), which can inflict a painful bite on humans, so be careful if you decide to handle them. Similar in appearance are "leafhopper assassin bugs" (genus *Zelus*), which are thinner than bee assassin bugs and readily take down smaller pollinators as well as vegetation-munching insects. If you are lucky enough to find these predators, they are quite amazing to watch.

Bees

As folks become more excited about native bees and pollinators, more funding is provided for research. In the past, very few researchers focused on native bees, so we simply do not have data or decent understandings of most bees or even pollinator species. There are large gaps in our knowledge concerning distribution, abundance, nesting locations, host plants, and other necessary resources for life cycles. Similarly, there is little information on how habitat management interacts with pollinator populations, potential stressors like parasitoids, and the habitat resources they depend on. To make matters worse, we are aware of a global decline in insects, and data show that the declines are not evenly distributed across areas or species. Our lack of knowledge only exacerbates the problems associated with declines, while also making conservation efforts to rebuild populations difficult to design.

Data suggest that habitat loss and pesticides are the leading causes of insect declines, but data are building that climate change is synergistically making these worse. In addition to these factors, invasive species, pollution, and other stressors are adding to insect declines. In North America, agriculture and urban expansion drastically alter landscapes and plant communities. Agriculture includes row crops,

A mason bee (genus *Osmia*) resting on a giant hyssop (genus *Agastache*).

The massive volume of habitat loss is hard to understand because there are so many ways habitat is lost. Here complete removal of habitats and replacing them with fossil fuel infrastructure clearly shows localized devastation but does not convey the continued killing of organisms at lights and flares, and the harm caused by polluted rainwater captured in battery basins.

orchards, pasturelands to raise animals, and the pesticides used to kill pests. Row-crop agriculture practices maintain large acreages of barren areas for most of the year, with floral resources available for only a small portion of the year if the crop blooms at all. Orchards also tend to provide floral resources for only a short time. Both areas are heavily treated with pesticides that harm insects. Cattle pastures are often managed by ranchers with broadleaf herbicides to promote non-nectar-producing grasses for cattle feed. Cattle grazing alone in wild areas can be very disruptive to floral resource availability, especially in overgrazed areas, leading to overall habitat degradation. However, positive changes are taking place. Many ranchers in North America are embracing more ecologically friendly methods to manage their lands. Methods like restorative grazing, permaculture, and ecological management can be very beneficial to local ecosystems, increase plant biodiversity, and even mimic some of the roles that were filled by extirpated animals.

Data continue to show that increasing flowering forb abundance and plant diversity positively correlates with native bee and butterfly abundance and diversity. These findings have led to many organizations producing messages urging people to plant pollinator plants, an incredibly important step in restoring native habitat. Messaging from these organizations can be found in countless articles, blogs, websites, and memes promoting native flower gardens as the best way to help native bees and butterflies. Most of these messages, however, ignore the incredibly more complicated aspects of creating good pollinator habitat. Although the messaging is correct—that pollinator plants are important—most native plant species are not purchasable or attainable by landowners. This leads to a select few plants being promoted, while the overall needs of species to carry out their life cycles are also overlooked. In other words, planting native plants offers a selection of meals for wildlife, but falls short on making complete habitats.

A transmission line right-of-way seeded for pollinators. Narrow corridors like this increase floral resources in an area and are often adjacent to sufficient nesting resources for many species. Larger acreages of flowers that can be more than a mile across, such as in agricultural fields and solar farms, are less accessible for many wildlife.

Insects in general rely on multiple resources in their habitat throughout their life cycle. Necessary resources for each species differ according to life stage and reproductive status. Habitat for native bees includes floral resources that they can forage on, areas to nest in, spaces to shelter in, and often other resources, like access to water and mud. All of these resources must be within foraging distance from the nest. Depending on the size of an adult bee, reasonable foraging distances may be less than half a football field for small bees and up to a mile (1.6 km) for larger bees.

The majority of native, solitary bees in North America build their nests in the ground. This is true for about 70% of bee species. Stem nesting, which includes bees that actively clear out stems or select hollow stems aboveground, is the second most common behavior. Cavity nesters are bees that build nests in structures they did not create, including hollow stems, snail shells, holes in rocks, areas between loose bark and trunks, and other small gaps in hard surfaces. Except for bee biologists, cavity-nesting bees are usually lumped in with soil- or stem-nesting bees, depending on where they prefer to build their nests. For example, many leafcutter bees (genus *Megachile*) are cavity nesters, but are considered stem nesters when they use bee hotels and ground nesters when they use rock crevices or subterranean tunnels. Even with all of these different nesting behaviors, many people assume all bees live in hives (likely due to do the popularity of the agricultural, non-native honeybees), but hive nesting is restricted to bumblebees and a few eusocial bees (those that live in a cooperative group) in our native fauna.

Of the 20,000 plus species of bees, more than 95% are solitary. This means labor is not divided, and only one adult creates provisions for its young. In most solitary bee species, adult females create nests one cell at a time. Each cell is created, provisioned

MINIMUM FLORAL COVERAGE

Unlike for livestock and game mammals, we currently do not have sufficient data on bee species to know how small a garden can be that will solely support a healthy bee population. Data show that native bees are limited in how far they can forage, so the maximum area that will support a single bee is limited to the farthest a bee can fly from its nest.

In robust habitats, data suggest that medium-size native bees typically forage no more than 150 feet (73 m) from their nest. Assuming a high estimate of 10% of the wild vegetation providing usable floral resources for bees, we can approximate that a 1,674 square foot (155 m^2) or 40- by 40-foot garden (12 × 12 m) should be sufficient as a solitary habitat. Smaller bee species (e.g., genus *Lasioglossum* and genus *Perdita*) will likely do all right with more compact gardens. Luckily, neighborhoods often have some supplemental forage for bees, so if an area can only support a smaller garden, native bees should be able to persist.

A parking-lot garden bed with ample space for a pollinator garden; it could support native bees with a more dense native-plant arrangement.

with pollen and often nectar, and then an egg is laid before the cell is sealed. Larvae develop on their own and emerge as adults without any care. Adult female bees select nest sites based on biotic and abiotic factors, including floral and nesting resource availability, soil texture, soil moisture, surface rocks for protection, vegetation cover, slope, and the aspect of the area. Each bee species has a different suite of preferences for each of those factors. At this time, we do not have robust data on ground-nesting bees, as they are the least studied group of bees, even though they are the most prevalent. Scientists have published research on the nests of between 500 and 600 species

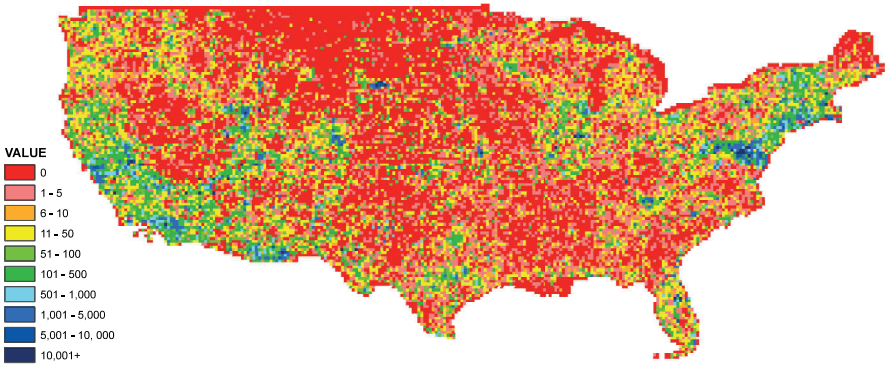
An aggregation of chimney bee (genus *Diadasia*) nests in a footpath in Oklahoma. Promoting these species in gardens requires dry, compact, barren, sandy clay soils. Similar soils are often found around fence lines and concrete.

of ground-nesting bees. Of the species that have been studied, the majority of the work is limited to small portions or even single sites within their range. From these studies, we can make inferences on researched species' needs, as well as extrapolate to species yet to be studied.

— Ground-nesting Bees

Using the little nest data available, soil texture seems to be the most important factor in nest-site selection for ground-nesting bees. The texture of the soil can be described by citing the percentages of the three particle types: clay, sand, and silt. If you are interested in classifying your own soils, see the soil-classification triangle (ternary diagram) and how to identify soils in the "Soils" section of chapter 1. To date, the majority of described ground-nesting bee nests have been found in soils dominated by sand and sandy clay, with a few nests occurring in sandy loam soils. This provides a good starting point for creating nesting sites. However, there are many soil characteristics that have not been investigated in terms of how they affect nest site selection. This includes preferred soil compactness (how well the soil holds water), pH, soil temperature, gas exchange, and so on, but in time this information will be gathered. Until then, providing a diversity of soils with varying compaction and exposure is the best way to provide potential nesting sites for ground-nesting bees. There is also a fair amount of bias in the regions where native bee nests have been studied, as many previous researchers in North America focused on the deserts of the Southwest. So, if you want to add to the knowledge of bees, submit soil texture data from nests you do find to community science projects. Even writing the soil description in an iNaturalist observation of the bee is helpful.

It is easy to encourage ground-nesting bees to nest in your yard, even if you do not know which species are in your area. Start by picking an area at least 1 square



A depiction of observations reported around the United States for bees, excluding honeybees. Most areas are poorly sampled.

foot in size, in full sun, where water will not collect. Double-check the area to make sure bees are not already nesting there. If they are, leave the area as it is. If there are nests, but you aren't sure if they are bees, survey the area for newly removed soil. Take the time to wait and see which insects are entering and exiting. If you cannot identify the specific insects using that area, try to photograph them and post to online platforms like iNaturalist.org and Bugguide.net, in the hope that an expert can identify them.

Once an area is selected where there are no bees nesting, dig the soil down a foot (0.3 m) to a foot and a half (0.5 m). Crush the removed dirt and remove any rocks larger than an inch (2.5 cm) in diameter. Depending on the soil texture, you may want to add some clay or sand so the soil can be more easily dug into by bees. Described soils of nests range from 30% to 98% sand, with clay and/or silt making up the remainder. This gives us parameters of roughly 60% sand, 30% clay, and 10% silt for soils that many species prefer to use. Once the soil is amended to the target profile, the soil can then be placed back in the hole and lightly packed to improve stability.

Depending on which species you are trying to encourage to nest, soils can be left mostly bare or have some vegetation trailing across the area. Check local resources to see if species in your area have had their nest sites described. Rocks and pebbles of different sizes, shapes, and colors can also be spread over the surface. Research shows a light covering of pebbles is preferred by nesting bees; the pebbles likely help bees identify their nest entrances. If there is enough room on your property, you can encourage different species by creating multiple areas with different soil types. These areas do not need to be in planter beds and are perfect for areas near HVAC units, fence lines, and other places on a property with less traffic.

— Stem- and Cavity-nesting Bees

Some cavity-nesting bees like orchard bees (genus *Osmia*) and leafcutter bees (genus *Megachile*) can be attracted to yards using hollow stems or bee tubes in sheltered areas. These are commonly referred to as bee hotels. In the early 2000s, bee hotels started to become more common, but the commercially available designs were poor. Bee hotels that are well designed and carefully taken care of are great additions to any garden. Conversely, bad designs and unmanaged hotels can be very detrimental to local native bee populations. Many designs have too many nests, are too short, or have incorrectly sized openings, and few instructions exist on cleaning and replacing nests annually. To properly encourage native, stem-nesting bees in your yard, you will likely have to build your hotel. The most important characteristic of a bee hotel is a limited number of nests. Stem-nesting bees naturally use or create holes that are barely larger in diameter than their bodies. Smaller bees, like species in the genera *Ashmeadiella*, *Ceratina*, and *Hylaeus*, use smaller diameter (and shorter) tunnels compared to larger bees like those in the genera *Anthidium*, *Megachile*, and *Osmia*. If you decide to hang up solitary bee nest boxes, those too should be tucked away from the harsh midday sun. Entrances should face east to northwest, and the entire structure should have some covering to protect it from the sun and rain.

Studies observing bee hotels over time have documented bee hotels becoming infested with parasitoids, non-native bees, and other nest pests, like pollen mites, mildew, and mold. In arid regions, stem nesting is less common than soil nesting, and adding a bee hotel to gardens in these areas can facilitate the spread of non-native bees. Another important difference for stem-nesting bees is that they rarely re-use cavities from year to year in the wild, whereas ground-nesting bees return to the same

A commercially sold "bee hotel" that lacks the correct proportions for most nesting bees. The tunnels are too shallow for their width, and the hotel cannot be cleaned.

space. It is possible stem nesters generally have more options, as many bees use the old, excavated cavities of beetles and dry stems grown the previous year to build their nests.

Stem-nesting blocks, or bee hotels, are commonly sold in stores to improve nesting resources; however, many designs are flawed. One of the most common problems with bee hotels is that they are too short. Bees can control the sex of the egg they lay; females are laid first in stem nests, and the last two or three cells are male. When the structure is too short, the male to female ratio increases, causing a decline in pollination services. Stem-nesting blocks are used by a wide variety of insects, including potter and spider wasps, caterpillar-hunting wasps, and bees (both native and non-native). It is a good idea to keep these away from butterfly gardens, as caterpillar-hunting wasps hunt the butterflies you are trying to create habitat for. Therefore, any yard that is enhanced for stem-nesting bees should keep nest density low, and nests should be cleaned or replaced every year.

RIGHT: An old tree wound exposes the tissue below the living cambium. This wood is fed upon by a variety of insects including tunnel-forming, long-horned beetle larvae (family Cerambycidae). When they mature and exit the wood as beetles, their tunnels are used by various cavity-nesting insects including solitary bees.

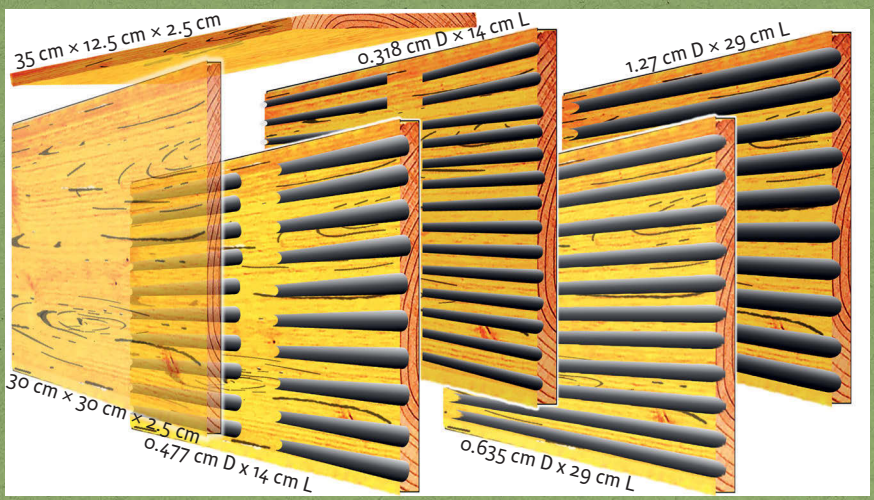
A commercially available bee nest hotel made specifically for orchard mason bees (genus *Osmia*). These tubes will be used by some other medium-size cavity nesters as well.

BEE NEST

Using a wood router to make bee hotels is better than drilling holes into blocks of wood as it is difficult to drill tunnels that are the necessary length for larger bees. Solid-wood boards that are 1 inch (2.5 cm) thick work best when using a router. The width can be between 4 inches (10 cm) and 12 inches (30 cm), with a maximum length of 12 inches. For larger bees that nest in cavities, boards can be cut to 8 to 12 inches (20–30 cm) in length. Layers can be secured with lightly tightened screws to seal the tunnels. Note that overtightening screws can lead to more warping, which exposes tunnels. Another option for securing the layers together is to use C-clamps and wood glue. If the design uses screws, drill a hole in each corner of every layer that is smaller than the screw diameter. Placing the drilled holes in the same spot on each layer is important for sealing the tunnels. One board will not have tunnels because it will seal the tunnels. Cut one board to extend an inch or two (2.5 or 5 cm) beyond the tunnel entrances to function as a roof. Secure it to the outside layer without tunnels for repeat use of these two layers.

After the boards are cut to size, use the wood router and a 1/8-inch (3-mm) bit to cut 4-inch-long (10-cm-long) grooves from the edge of the board into the center of the wood. Do this on opposite sides of the board, on the same face, to increase microclimate diversity. Repeat this step with bits up to ¼ inch (6 mm). For wider tunnels, use ¼-inch bits to 7/16-inch (11-mm) bits and cut 8-inch- to 9-inch-long (20- to 23-cm-long) tunnels into a board, all on the same face. You can alternate ends of the board to decrease the number of entrances on one side and increase the microhabitats of the bee hotel, which can reduce

A diagram of a bee-nest block design used to study bees in the Great Plains. Multiple sizes of tunnels with different diameters support a wide array of cavity-nesting bees.



Solitary cavity-nesting bees build cells starting farthest from the entrance. Females are laid in the deeper cells, with males in the last few cells. When a nesting apparatus is short, males become too abundant.

parasitism of the nests and increase the number of species using the blocks. Naturally, tunnels are not straight lines, so it is perfectly fine if the tunnels are wonky.

Clean the boards thoroughly and wipe them down with a sterilizing solution like rubbing alcohol or a 20% bleach mix. Let the boards dry. Once they are dry, secure the layers together and place them in a protected area that receives morning sun to no direct sun. Tunnels should be near horizontal once installed. Like tubes and other bee hotels, layers should be replaced annually. In the spring, replace used nest blocks and hotels.

Cleaning and Care

Stem-nesting bees usually do not naturally nest in aggregates; when they do, parasitic insects can easily find and harm all of the nests. Therefore, it is best to spread the nest blocks around your yard, including areas like the side of the house and away from gardens to limit parasitism. Nesting blocks can easily become infested with parasitic bees, pollen mites, and molds and mildews that typically only affect a single nest naturally. Keeping small bee hotels and replacing the nest blocks each year allows you to control these pests and enables your bee populations to grow.

In the spring, replace used nest blocks with new hotels. Place the block with bee nests in a small, closed area—like a windowless shed, cardboard box, or paper bag—with a clear exit hole that bees can escape from. Make sure ants and other animals will not be

Mature *Osmia* bees sit next to their natal cells and cocoons. Tunnels were made following the directions on the previous page.

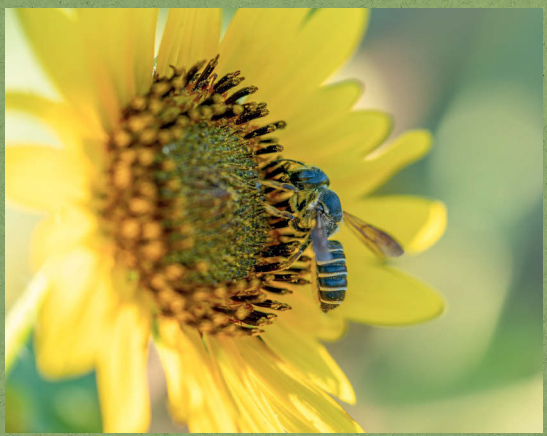
continued overleaf

BEE NEST *continued*

able to raid the nests. Leave the hotels in these areas through August; this will allow bees to emerge and leave, but not encourage them or other bees to re-use the nesting blocks.

Other Structures

Bird nest boxes are sometimes used by a few bumblebee species. In the wild, many bumblebees use old rodent nests and tree cavities. To promote bumblebee use of a nest box, secure the box close to the ground near dense vegetation. You can also place in the box natural cotton, milkweed seed fluff, and small, dry leaves, which the bumblebees use to protect their nests. Synthetic materials, including dryer lint, plastic straws, and toy stuffing, should not be used.



A leafcutter bee (genus *Megachile*) on a sunflower (genus *Helianthus*).

Soil matrices are not likely to change from year to year, which is likely why ground-nesting bees build their nests in the area where they emerged. Ground-nesting bees typically dig one entrance, excavating soil to the surface until they complete their first brood cell. The tunnel to the first brood cell is then filled in with excavated dirt from the second. It is thought that this behavior helps prevent parasitoid insects and predators from gaining access to multiple young at one time. If the bee runs out of space to place newly excavated soil, it then brings soils to the surface until the brood cell is completed. The deepest soil nest recorded so far was 3 meters, or roughly 10 feet deep, in a sand dune. Most soil nests, however, range between, say, 4 inches (10 cm) to 18 inches (45 cm) deep. Unlike bee hotels, soils do not need to be replaced, but they should be weeded to prevent roots from filling in the nesting areas.

A robber fly (family Asilidae) feeds on a native bee. Bees are the food source of many predators, such as other arthropods, birds, and amphibians.

Plants and humans are not the only organisms that rely on bees for their survival and diverse diets. Bees are also the main diet staples for a variety of animals, including arthropods like assassin bugs, bee flies, cuckoo bees, spiders, velvet ants, and a variety of parasitoids. Predators of bees also include vertebrates, especially birds. This means that many animals are trying to eat bees, and there isn't a period in their life cycle where they are safe. This section provides a brief introduction of parasites, parasitoids, pests, and predators, known wholly as natural enemies, as they pertain to bees. Parasites feed directly on another organism and usually do not cause the host's death. Parasitoids also feed directly on their host, but their feeding or development tends to kill the animal they feed on. Pests of bees are organisms that indirectly harm bees, like pollen mites and mildew that can destroy food resources. Predators capture and kill bees. Every garden hosts natural enemies of native bees. Some natural enemies might even be encouraged as they also negatively affect less-desirable insects that infest plants or are charismatic wildlife like praying mantises. It is important to be mindful of how wildlife might interact in your yard.

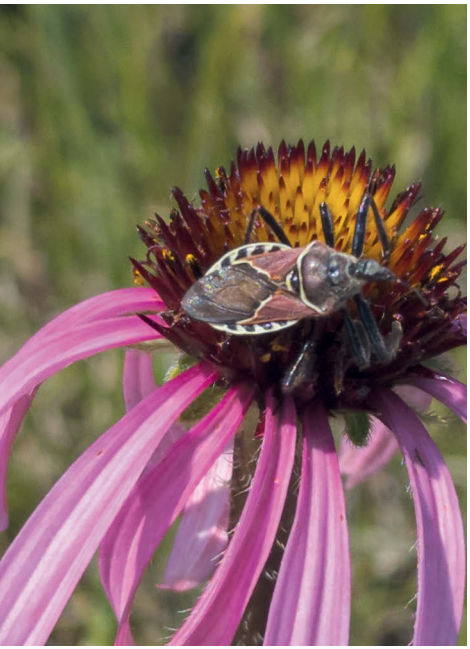
Tracking a bee's life cycle and looking at all the dangers they are exposed to allows us to see how bees are critical in the food web. This exercise focuses on solitary bees, as roughly 95% of bee species are solitary. As the mother bee is out collecting pollen and nectar to provision the cell (a process that takes numerous trips per cell), a cuckoo bee can enter the nest and lay its egg in the incomplete cell, unbeknownst to the mother bee. Once the cell is fully provisioned, the mother bee then lays her egg in the cell with the cuckoo bee egg. The cuckoo bee larvae hatches, consumes the intended egg/larvae, and then develops, using the provisions. There is also a possibility for parasitoids to lay their eggs in the cell, or crawl in, or, in some cases, enter and parasitize completed cells. The parasitoid larvae emerge and enter the bee larvae to carry out the

life cycle. Once inside the bee larvae, the parasitoid slowly consumes the larvae from the inside out, eventually killing the larvae before emerging and pupating in the cell.

If the mother bee manages to complete the cell without cuckoo bees or parasitoids infiltrating it, the young larvae start to develop, but it is not free from danger. Pollen mites, molds, mildews, and a slew of pests can still take over the nest, killing the young bees or pupae. Incredibly, some desert bees spend more than two years in their nest waiting for the right environmental signal that it is time to emerge. Once the young bee finally pupates and the flight season begins, it must crawl out of the nest. For many cavity-nesting bees, this can mean waiting for their siblings to emerge. For example, in bee hotels, sometimes a different bee species will take over the tunnel, either by force or because the first mother bee has succumbed to a predator and is no longer actively building a nest in the tunnel. This can lead to the death of the original young, as they can mature prior to the new nesting bee species, and without mandibles made for chewing, they may not be able to get past the new cells or pupae. An event like this is much less likely to occur in ground-nesting bees, which have to dig out of their cells and emerge through the dirt placed in their tunnel while their mother continues to make new cells for its siblings along the main chamber (see the "Ground-nesting Bees" section, above). Researchers know very little about this process and how the young bees manage to navigate through the soils.

Once the bees mature and emerge, they find a nest site and start building their nests. A single pollen-collecting trip is full of predation risks for adult bees. Individuals are at most risk when they are entering and exiting nests and foraging on flowers. Observations of most ground-nesting bees show that adults do not spend much time near the entrance of their nests; they try to get in and out quickly. Even with their quickness, various bird species, like Northern Mockingbirds (*Mimus polyglottos*), hunt bees by running around nest aggregations and picking off adults as they enter and exit nests. Due to the high predation rate on bees, it is important to consider how other wildlife, like birds, predatory insects, and lizards, will affect your bee populations. Some predation of the target species is natural and keeps the habitat healthy. However, keeping nesting areas clear of perches and ambush sites helps keep nesting bees a little safer. Similarly, placing barriers like chain link fences and grates above nest sites can limit predator access while allowing bees to fly through.

While bees (and other insects) are on flowers, they are susceptible to a number of predators, including crab spiders (family Thomisidae), jumping spiders (family Salticidae), predatory bugs (like wheel bugs, genus *Arilus*, and assassin bugs, family Reduviidae), and other ambush predators. Adults can also pick up a suite of nest parasites while foraging on flowers, as well as pathogens that can make them and their

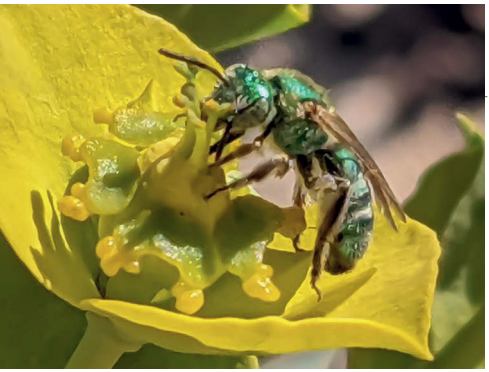


ABOVE LEFT: A bee assassin bug (genus *Apiomerus*) waits on a coneflower bloom for its next meal.

ABOVE RIGHT: An Eastern Kingbird (*Tyrannus tyrannus*) snacks on a dragonfly. Its diet also includes bees.

offspring ill. Gardeners can help reduce risk by planting areas with multiple species of flowers that bloom at different times. This creates conditions that force predators to move often and allows contaminated flowers to be visited less frequently.

It is also important to note that Western Honeybees (*Apis mellifera*) should not be kept "to help the environment." Honeybees are native to areas surrounding the Mediterranean and are an invasive, agricultural product in North America, much like feral hogs, rock pigeons, and burros. Even if you are using honeybees for honey production and to pollinate crops, honeybees still spread diseases to native bees. So it is best to avoid placing hives in areas with habitat intended for native bees. This likely goes against information you have heard from many campaigns that try to "save the bees" but mistakenly include honeybees. This misinformation is often due to a lack of ecologists and biologists sitting on those campaign steering committees. Keeping honeybees as a means to save the bees is like raising pigeons to save the birds. However, maintaining diverse habitats and implementing practices that mimic natural processes will benefit local pollinator populations.

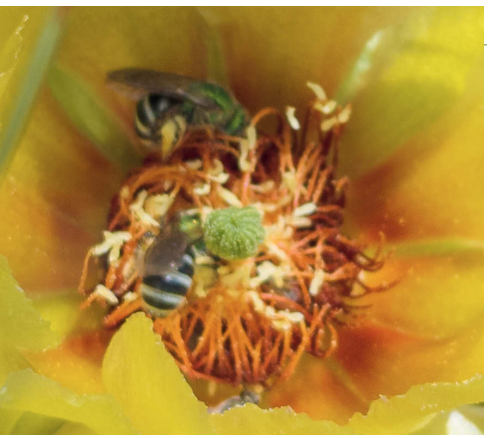


An unidentified sweat bee (genus *Agapostemon*) visiting a non-native spurge (genus *Euphorbia*). This genus of bees uses a wide array of nectar and pollen plants, which allows them to live in a variety of developed landscapes.

Select Bee Profiles

— ANGELES SWEAT BEE

Angeles Sweat Bees (*Agapostemon angelicus*) occur from the Rocky Mountains to the Mississippi River, and from Canada to Mexico. Nests are excavated in sandy soils with sparse to no vegetation; tunnels extend about 17 inches (42 cm) into the ground. Some bees nest alone, but many nest communally, with up to 30 adult females using the same entrance without caste differentiation, which is seen in some eusocial bees (those that live in a cooperative group) and most bumblebees. There does, however, appear to be partial division of labor for guarding and foraging roles. When multiple nests are located near one another, bees regularly switch nests and supposedly excavate their own cells. Cells are built at the end of lateral burrows that are refilled with soil after eggs are laid on pollen balls and sealed. Promoting this species is best done by offering a wide range of flowers (especially from the plant genera listed for the Bicolored Striped Sweat Bee, *Agapostemon virescens*) and deep, dry sandy soils with light compaction and sparse vegetation.



Two Bicolored Striped Sweat Bees (*Agapostemon virescens*) forage on a Plains Prickly Pear (*Opuntia polyacantha*) flower.

— BICOLORED STRIPED SWEAT BEE

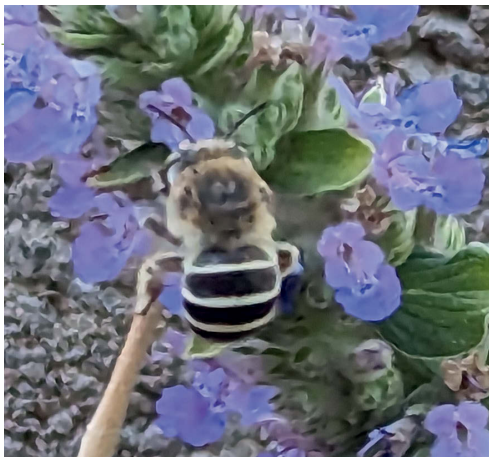
Bicolored Striped Sweat Bees (*Agapostemon virescens*) can be found throughout most of North America, including suburban neighborhoods, feeding on a wide assortment of flowers. Each year, they produce one generation that develops rapidly. Adults emerge from hibernation around mid-May and forage for a few weeks before beginning to build nests in soil, often in aggregations. The young develop and emerge in August and are active until the first frost, which triggers them to find overwintering sites. Nesting locations are extremely varied, from vertical hillslopes to flat, mostly barren areas. Reported soils vary from "sticky clay" to sandy loam, with no mention of compaction.

To encourage this species, make sure to provide blooms from May through October. When possible, provide a variety of barren, sticky clay to sandy clay soils. Adult bees overwinter in nests and possibly other underground nests of similar sizes. This species has been reported from 137 plant species from 95 genera, the most genera occurring in the Asteraceae, Brassicaceae, and Fabaceae families.

Plant genera used by these bees: *Agastache, Agoseris, Aloysia, Amorpha, Arctium, Arnica, Asclepias, Aster, Astragalus, Balsamorhiza, Borago, Brassica, Campanula, Carduus, Castanea, Centaurea, Chamaenerion, Chrysanthemum, Cichorium, Cirsium, Clarkia, Convolvulus, Coreopsis, Cornus, Cosmos, Crepis, Daucus, Dichelostemma, Diervilla, Echinacea, Eriophyllum, Eschscholzia, Escobaria, Eupatorium, Fagopyrum, Gaillardia, Geranium, Grindelia, Gypsophila, Helenium, Helianthus, Heliopsis, Heterotheca, Hieraceum, Hieracium, Houstonia, Hypericum, Hypochaeris, Impatiens, Ipomoea, Larrea, Lavandula, Liatris, Limonium, Lotus, Lythrum, Medicago, Melilotus, Monarda, Nepeta, Ocimum, Oenothera, Opuntia, Origanum, Potentilla, Prosopis, Pycnanthemum, Quincula, Ranunculus, Raphanus, Rhus, Rosa, Rubus, Rudbeckia, Salvia, Senecio, Silphium, Solidago, Sonchus, Sorghastrum, Sphaeralcea, Symphoricarpos, Symphyotrichum, Symphytotrichum, Syringa, Tagetes, Taraxacum, Tellima, Tradescantia, Trifolium, Verbascum, Verbena, Wyethia, Zinnia,* and *Zizia*.

— CALIFORNIA DIGGER BEE

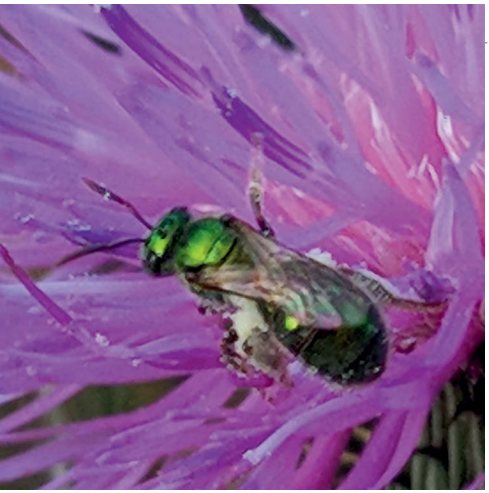
California Digger Bees (*Anthophora californica*) are large-bodied bees common in urban environments and natural areas. Most often, these bees can be found in open habitat with some vertical vegetation structure like shrubs and trees. They are fast flying and rarely sit still for long, but can be spotted hovering by plants. Nests are constructed in sandy clay, with entrances in bare soil or under medium-size to large stones. Adults fly all year when it is warm and peak in early summer. To encourage this species to visit a landscape, include flowering plants with prolific blooms and lightly compacted, sandy soils, with little to no vegetation cover.



A California digger bee (genus *Anthophora*) hovers around a non-native Russian Sage (*Salvia yangii*) bush in a New Mexico garden.

Plant genera that California Digger Bees have been reported from are: *Acmispon, Allionia, Amsinckia, Astragalus, Baccharis, Berberis, Berlandiera, Brazoria, Cakile, Carduus, Cevallia, Chilopsis, Cirsium, Citrus, Cosmos, Dalea, Delphinium, Dermatophyllum, Dudleya, Duranta, Echinocereus,*

Eriodictyon, Gaillardia, Geranium, Grindelia, Hedeoma, Helianthus, Heliotropium, Hesperis, Hoffmannseggia, Ipomoea, Kallstroemia, Lantana, Larrea, Lepechinia, Leucophyllum, Lippia, Lotus, Lupinus, Lycium, Machaeranthera, Melilotus, Mimosa, Mimulus, Monarda, Oenothera, Oxalis, Parkinsonia, Penstemon, Phacelia, Physaria, Poliomintha, Potentilla, Prosopis, Psoralidium, Psorothamnus, Raphanus, Ribes, Rosa, Salvia, Scutellaria, Senecio, Silene, Solanum, Stachys, Tithonia, Trichostema, Verbena, Verbesina, Vicia, Vitex, and *Zinnia.*



A Pure Green Sweat Bee (*Augochlora pura*) visits a native thistle.

— PURE GREEN SWEAT BEE

Pure Green Sweat Bees (*Augochlora pura*), also known as Pure Gold Green Sweat Bees, are small and quite common near forested habitats within their range. These bees modify existing tunnels in damp, later-stage, decaying wood to make their nests, which can be extremely variable in shape. In general, cells are made close together, with entrances to the tunnel that are sealed off. Within a piece of wood, tunnels can be fairly straight to spiraled, allowing bees to exit when they mature. Up to three generations are produced each year.

To encourage these bees in your area, place old logs in shaded areas where they will not dry out. Adults feed on a variety of flowers and forage throughout the growing season, so it is important to incorporate plants with flowers throughout the year.

Associated plant genera are: *Agastache, Ageratum, Alliaria, Amorpha, Ampelopsis, Apocynum, Aralia, Asclepias, Aster, Baccharis, Balduina, Barbarea, Bidens, Brassica, Callicarpa, Campanula, Castanea, Centaurea, Chamaecrista, Chamaedaphne, Chrysanthemum, Cichorium, Cirsium, Claytonia, Convolvulus, Coreopsis, Coronilla, Crataegus, Cypripedium, Desmodium, Diervilla, Echinacea, Elephantopus, Enemion, Epilobium, Erigeron, Eryngium, Erythronium, Euphorbia, Galinsoga, Garberia, Helianthus, Hieracium, Hydrangea, Hydrophyllum, Hypericum, Hyptis, Ilex, Impatiens, Ipomoea, Lactuca, Lobelia, Lonicera, Ludwigia, Magnolia, Malus, Melilotus, Mentha, Monarda, Nepeta, Neptunia, Oenothera, Origanum, Packera, Pentas, Persea, Photinia, Phytolacca, Pityopsis, Polemonium, Polygonella, Prunus, Quercus, Ratibida, Rhododendrom, Rhus, Ribes, Rubus, Rudbeckia, Salix, Salvia, Scrophularia, Senecio, Serenoa, Sideroxylon, Smilax, Solidago, Spirea, Symphyotrichum, Taraxacum, Tradescantia, Trifolium, Vaccinium,* and *Veratrum.*

— GOLDEN SWEAT BEE

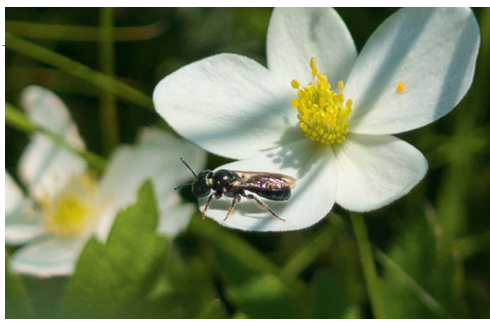
Golden Sweat Bees (*Augochlorella aurata*) can be found east of the Rocky Mountains to the Atlantic Ocean, and from Canada to Mexico. They are small, ground-nesting, eusocial (living in a cooperative group), brightly colored generalist bees that are common in suburban habitats. Colonies are founded by a female in early spring and persist through the growing season until the first freeze. Nests are reported from a variety of habitats, including forests and grasslands in areas of sandy to sandy clay soils with moderate vegetation cover. The depth of nests ranges from 2 to 10 inches (5–25 cm).

Two female Golden Sweat Bees (*Augochlorella aurata*) on a Miniature Barrel Cactus (*Thelocactus setispinus*) bloom.

Bees have been reported from 185 plant genera, with some preference to those in the families Asteraceae, Brassicaceae, and Fabaceae. You can encourage populations of this bee by providing ample, native plants with blooms available throughout the growing season and areas of lightly compacted sandy soils that reach up to a foot (30 cm) deep in dry to semi-dry areas. Bees overwinter in these nests, so avoid disturbing the soil after installation.

— SMALL CARPENTER BEES

Small carpenter bees (genus *Ceratina*) are fairly common and easily overlooked due to their small size and dark colors. At first glance, most species appear black, but many have dark metallic hues of blue or green, and a light spot on their "nose" that is biologically termed a "clypeus." Most species are generalists, feeding on a variety of flower nectar and pollen, from tiny spurge flowers to large cactus flowers. Nests vary in social types and are constructed in the stems of various soft, woody plants, which the females hollow out. Stems used for nesting include, but are not limited to, brambles (genus *Rubus*), elderberries (genus *Sambucus*), sumacs



A small carpenter bee (genus *Ceratina*) on a Meadow Anemone (*Anemone canadense*) from native prairies in North Dakota. These bees are common throughout North America and usually nest in pithy stems.

(genus *Rhus*), sunflowers (genus *Helianthus*), and invasive teasels (genus *Dipsacus*). Females are loyal to their nests and care for their young.

Data show that plant species and location are important for nests. Some Small Carpenter Bee species prefer to nest in stems exposed to direct sunlight, while others prefer stems in the shade. To improve habitat for these bees, use plants they are known to nest in and allow old, dead stems of those plants to remain standing. Stems can also be bundled and secured in shady spots, or you can create a bee hotel. Small carpenter bees have been reported from more than 350 plant genera. These bees are generalists, so they benefit from plantings based on most pollinator garden-plant lists.

Two male Unequal Cellophane Bees (*Colletes inaequalis*) sit on the ground in a nest aggregation among lawn plants, in Ithaca, New York. These bees emerge early and often nest in mowed areas, but rarely sting.

— UNEQUAL CELLOPHANE BEE

An early-spring bee that is common throughout the eastern United States and parts of central Canada, the Unequal Cellophane Bee (*Colletes inaequalis*) can often be found in suburban environments. They are ground nesters that readily use roadsides, forest edges, and mowed areas with sandy soils. Foraging has been reported from many spring-flowering trees, including maples (genus *Acer*), and a variety of herbaceous plants, including dandelions (genus *Taraxacum*), Shepherd's Purse (*Capsella bursa-pastoris*), and spring beauties (genus *Claytonia*).

You can encourage Unequal Cellophane Bees using upland mowed areas with sandy soils. Amended soils should extend more than 12 inches (30 cm) deep and more than 12 inches (30 cm) wide. When nests are active, mowing should be restricted to late evening, near sunset. Planting willows (genus *Salix*), maples (genus *Acer*), serviceberries (genus *Amelanchier*), apples (genus *Malus*), cherries (genus *Prunus*), and early-blooming herbaceous flowering plants provides ample food.

— SUNFLOWER CHIMNEY BEE

Sunflower Chimney Bees (*Diadasia enavata*) are medium-size to large ground-nesting bees specializing on pollen of plants in the Asteraceae family (asters, daisies, sunflowers). These bees are usually found around sunflower patches between May and September, especially in agricultural settings. Females excavate shallow nests, about 4

A Sunflower Chimney Bee (*Diadasia enavata*) forages on a Common Sunflower (*Helianthus annuus*) next to a flower crab spider (family Thomisidae) taking down a smaller native bee and a blister beetle (family Meloidae).

inches (10 cm) deep, in densely packed, sandy to silty clay soils with dense aggregations along roadsides.

To promote this species, grow an abundance of native sunflowers (genus *Helianthus*), gumplants (genus *Grindiella*), and thistles (subtribe Carduinae), with a diversity of other large-flower plants. Provide areas of densely compacted, sandy soil to encourage nesting.

— LIGATED FURROW BEE

One of the more common bees in North America is the Ligated Furrow Bee (*Halictus ligatus*), a generalist bee that occurs from Canada to Colombia, coast to coast. Unlike most native bees, Ligated Furrow Bees are eusocial; they live in a cooperative group in which there is division of labor, with a queen and a handful of workers. It is also common for multiple queens to nest next to one another, forming what are known as nest aggregations. Only new young queens survive the winter in regions with freezing winter temperatures.

A colorful morph of the Ligated Furrow Bee (*Halictus ligatus*); most specimens are dark with light-colored bands of hair on the abdomen.

Queens start burrows on sunny, gentle slopes or flat areas that are barren or sparsely vegetated. Nests continue to deepen as the season progresses but are abandoned if plants get too dense near the entrance. Nest structure can be deep or shallow, with no two nests the same. However, all nests include a main tunnel and usually have secondary tunnels. Bees create a small chamber to provision with pollen and some nectar before an egg is deposited and the chamber sealed. The young bee develops undisturbed and emerges on its own later that year. Observations of nesting soil are quite varied and include soft, garden loams, mixed sandy clay, firm silty soils, and bare clay paths.

If you want to encourage Ligated Furrow Bees to nest in your yard, choose a sunny area that will not get too thick with vegetation. Dig out an area that is a minimum of a foot (30 cm) wide and a foot deep. Fill the area with a soil similar to the ones listed above and amend as needed. Adding a bit of coarse sand helps make the soil more stable. Lightly pack down the soil so that bees can easily dig but the soils do not collapse. The soil should be resistant when poked with a stick, but pliable enough for the stick to sink into the soil. When the stick is removed, the soil should stay in place.

A female Orange-tipped Woodborer bee (*Lithurgopsis apicalis*) foraging on a prickly pear (genus *Opuntia*) flower in eastern Colorado.

— ORANGE-TIPPED WOODBORER

Adult Orange-tipped Woodborers (*Lithurgopsis apicalis*) are regularly seen on cactus flowers, including prickly pears, chollas, and barrel cacti. Females excavate nests in stalks of dead and dying genus *Agave* and genus *Yucca* flower stalks. This species is common in the arid Southwest. Encouraging this species in an area involves planting cacti and leaving dead agave plants after they have bloomed and yucca stalks.

A leafcutter bee (genus *Megachile*) foraging on a sunflower (genus *Helianthus*). Sunflowers are amazing additions to gardens because they support a variety of wildlife, including pollinators.

— ALFALFA LEAFCUTTER BEE

One of the more widely distributed bees in North America, the Alfalfa Leafcutter Bee (*Megachile rotundata*) is visually similar to many other leafcutter bees and is not native. They occur in herbaceous and low-growing woody vegetation communities, but avoid forests and shady areas. Although this species is not native, it is important for some producers, and adding resources to the landscape to promote this species will likely encourage other native leafcutter bees as well.

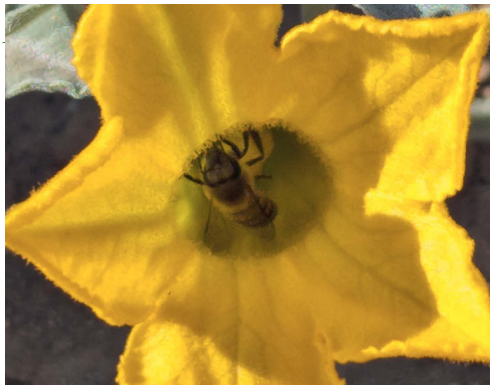
Females nest in cavities they did not create, including reeds, mortar, stem blocks (bee hotels), and abandoned tunnels in the ground.

Cells within the nest are lined with plant material and can include leaf petals or leaf discs. Adults have been collected from over 200 plant species. Populations are thought to move with floral availability within the landscape, and multiple generations are produced each year. The last generation overwinters in the nest and emerges the following year.

To promote this species, plant a diversity of native, flowering annuals and perennials to provide an array of blooms throughout the growing season. Placing artificial nests with tubes in open areas will encourage nesting.

— PRUINOSE SQUASH BEE

An important agricultural bee that pollinates gourds and squash plants, the Pruinose Squash Bee (*Peponapis pruinosa*) historically foraged on native plants in the Cucurbitaceae family. Agricultural practices have created suitable habitat for one of the key host plants, Buffalo Gourd (*Cucurbita foetidissima*), which now has a much farther northern range than in historical records. This expansion, along with crop production of watermelons, pumpkins, and zucchini, has increased the range of the Pruinose Squash Bee as well. The current range now extends across most of the United States and Mexico.



The flowers of Buffalo Gourds (*Cucurbita foetidissima*) are large and brilliant in color. These and other squash plants are the food source for Pruinose Squash Bees (*Peponapis pruinosa*).

To encourage these bees, plant native and crop squash plants and provide loamy to sandy clay soils below the growth of the plants. Amended soils should extend 30 inches (75 cm) and be more than 24 inches (60 cm) wide. Nests have been documented to occur in irrigated areas with good drainage, but moisture levels were not reported. Bees take nectar from nearby flowers, including sunflowers (genus *Helianthus*) and bindweeds (genus *Convolvulus*).

— HIBISCUS TURRET BEE

Hibiscus Turret Bees (*Ptilothrix bombiformis*) are fairly large, native bees that occur in much of the eastern half of the United States. Adult bees are often seen on mallow (family Malvaceae) flowers, including rose mallow (genus *Hibiscus*), but also utilize Buttonbush (*Cephalanthus occidentalis*), coneflowers (genus *Echinacea*), ironweeds (genus *Vernonia*), moonflowers (genus *Ipomea*), plume thistles (genus *Cirsium*), and verbenas (genus *Verbena*).

Two Hibiscus Turret Bees (*Ptilothrix bombiformis*) forage on a native hibiscus flower (genus *Hibiscus*) in Louisiana.

Females excavate solitary nests, usually near other nests, in compacted, exposed, clay-dominated soils. Each nest has one to three cells and can be as deep as 4 inches (10 cm), but usually a cell is not deeper than 3.5 inches (8 cm). Larvae develop and overwinter in their last larval stage. Folks most often encounter nesting sites in paths and roads through wetlands. Standing water with undisturbed soil surfaces near nesting sites is important for this species because they transport water to loosen soils as they excavate nests. This species is unlikely to be in small suburban plots due to its nesting and foraging behaviors but may be present in areas adjacent to wetlands, nature trails, cattle ponds, and perennial water sources.

To encourage this species, provide cleared, compacted clay soils that are 4 inches (10 cm) deep in areas near standing water resources. Include an abundance of plants from the mallow family and other flowers listed above.

An Oblique Longhorn bee (*Svastra obliqua*) foraging.

— OBLIQUE LONGHORN

Ranging from coast to coast and from Canada to Mexico, Oblique Longhorns (*Svastra obliqua*) can be found in early-succession habitats, roadsides, and disturbed areas. These ground-nesting bees create nests in barren to slightly vegetated, fairly flat, sandy clay soils with full sun to dappled shade exposure. Females share nest entrances but build and provision their own cells. Nests are provisioned with pollen from flowers of the Asteraceae family, especially sunflowers and related genera.

To promote this species, plant a diversity of sunflowers and allies to provide an abundance of blooms. Nesting areas should have sandy to sandy loam soils 24 inches (60 cm) deep, with light compaction and few to no plants covering the soils.

— EASTERN CARPENTER BEE

An adult large carpenter bee (genus *Xylocopa*) nectaring on prickly poppy (genus *Argemone*) in Alabama.

Eastern Carpenter Bees (*Xylocopa virginica*) are one of the largest native bee species in North America. Their active nest making, which is done by chewing into wood, makes many gardeners and homeowners consider these bees to be pests. However, there are many different ways to protect wooden structures from these bees nesting, including using metal screen covers. To make matters worse, the larvae are eaten by woodpeckers and flickers, which further damages structures but can be rather dramatic to witness. To encourage Eastern Carpenter Bees (or other members of the genus) to nest away from structures, secure scrap wood or split logs onto trees, posts, or other structures. Downward faces should be more than 6 feet (2 m) off the ground to provide preferred nesting resources. Adult males guard nesting areas by hovering nearby, which can be interesting to watch, and they cannot sting. Females can sting, and in some cases where nesting sites are limited, this species switches from being solitary to social. A subordinate female caste is reared that defends nests but does not help with caring for the young. In both solitary and social nests, young are cared for instead of left to develop on provisions alone, which is rare for solitary bees. Queens stay busy all day, either caring for the nest or visiting a wide range of flowers, which can add a nice energy to any garden.

Eastern Carpenter Bees have been collected from the following plant genera: *Agalinis, Asclepias, Aster, Baccharis, Balduina, Bejaria, Bidens, Borrichia, Calamintha, Callicarpa, Carduus, Centaurea, Chilopsis, Chrysopsis, Cirsium, Commelina, Dalea, Erigeron, Eupatorium, Euthamia, Gaillardia, Garberia, Helianthus, Heterotheca, Hieracium, Ilex, Ipomoea, Lachnanthes, Liatris, Licania, Ludwigia, Lyonia, Lythrum, Mimosa, Myrica, Oenothera, Opuntia, Palafoxia, Phacelia, Piloblephis, Pityopsis, Pluchea, Polygonella, Potentilla, Prunus, Pyrrhopappus, Quercus, Richardia, Sabal, Serenoa, Sida, Solidago, Symphyotrichum, Syngonanthus, Trifolium, Urena, Vaccinium, Verbena, Vernonia, Vitis,* and *Ximenia.*

Butterflies and Moths

One of the best ways to liven up a space is to plant butterfly and moth (order Lepidoptera) host plants. Host plants are the plants that caterpillars consume to grow into adults, and nectar plants are flowering plants the adults visit to feed. Most host plants produce flowers that brighten an area and feed a diversity of pollinators. There are lots of articles discussing which plants to add for target species, like Monarchs (*Danaus plexippus*) and swallowtails (family Papilionidae), but practically all articles ignore Lepidoptera ecology.

The majority of moths and butterflies have naturally low rates of survival in the wild (usually less than 5%) due to numerous natural enemies that feast on their larvae. Predators include beetles, birds, flies, spiders, wasps, and even some worms. Species also have to contend with parasitoids, diseases, and parasites. Data on wild populations have shown that habitats that seem to be best suited for butterfly species are more likely to have boom and bust years driven by natural enemies. This means that gardens with lots of resources are great habitats, so they attract and host many

BELOW LEFT: A freshly emerged, late-stage woolly bear caterpillar (subfamily Arctiinae) sits below its shed skin. Arthropods, including caterpillars, shed their exoskeleton to grow.

BELOW RIGHT: An Alluring Schinia Moth (*Schinia siren*) sits next to plant damage from an unknown caterpillar. Planning gardens with mixed plantings masks eaten leaves and denuded plants. Hungry caterpillars can completely defoliate plants, but without caterpillars and plant damage, we would not have moths and butterflies.

natural enemies that can harm the butterflies and moths the garden was planted for. To make matters more difficult, common predators like lady beetles (family Coccinellidae) and praying mantids (order Mantodea) are often encouraged by gardeners because they eat "pests"; however, they are generalist predators and eat desired caterpillars without hesitation. Other common predators include hover flies (family Syrphidae), jumping spiders (family Salticidae), lacewings (order Neuroptera), umbrella wasps (genus *Polistes*), and yellow jackets (genera *Vespula* and *Dolichovespula*).

Most gardens considered great habitat for their target butterfly or moth species are therefore good habitat for the predators and parasitoids of the target species. To prevent natural enemies from building up, you can do a few easy things. Some are more time-intensive projects, but there is a range of actions that will help increase the survival rates of caterpillars in your garden and reduce the presence of natural enemies. Most of the predatory insects and parasitoids (beetles, flies, wasps, etc.) feed on nectar. Growing larval host plants away from prolific blooming areas of your yard requires more energy for the predators to find the caterpillars. Similarly, it is a good idea to keep host plants separated and spread out across the yard, rather than in large groups. Grouping host plants together in a yard creates a small area for predators to search and can increase the mortality rate of caterpillars and pupae. Plants release chemicals when they are damaged to help heal wounds, and predators follow the smell of these chemicals. When plants are spread out, the scents are diluted, and predatory insects will have to fly farther and search longer before finding their prey. Lastly, every three to five years, you should cut the host plants back before butterflies arrive to prevent egg laying for the year. This mimics natural disturbances like large herbivore herds, fires, and habitat succession and is important to control the

An orb weaver spider (family Araneidae) sitting in its web. This is one of many predators that feed on butterflies. These spiders are also prey to other wildlife, including birds and wasps.

populations of predators and parasitoids that will establish. With no larvae to eat, predators will have to leave the area to find food for their young.

More time-intensive projects include surveying your yard for predators and building outdoor, screened rearing areas where you can clump host plants and caterpillars, now protected from becoming prey. Finding and moving caterpillars into the rearing area and releasing emerged adults require a fair amount of time each week. This can also lead to disease spread, as with *Ophryocystis elektroscirrha* (OE) in Monarchs (*Danaus plexippus*) and Queens (*D. gilippus*). Areas need to be cleaned, with old plant growth removed and new growth allowed to establish between generations. Caterpillars can also be monitored in the yard until they are about to pupate. A few specimens can be moved into a container for observation as they create cocoons or chrysalises. If adult butterflies emerge from all of the collected caterpillars, the area likely has low parasitoid populations. However, if most or all of the collected caterpillars fail to emerge but flies and wasps appear in the container, then action must be taken to dissuade butterflies from laying eggs for a full season. Older butterfly gardens that have had no precautions taken for predators and parasitoids are the most likely to have high mortality rates. Cutting back host plants the following year or moving all young caterpillars to protected cages can reduce predator and parasitoid populations. It is critical that gardeners also understand when their gardens are out of balance because factors that keep populations healthy are absent, preventative steps are necessary. (See the chapter 4 section "Monitoring, Responding, or Letting Nature Take Its Course" for more.)

No matter how much time a gardener commits to helping butterfly and moth species grow in their yard, it is important to understand that host plants will be eaten. As caterpillars grow, they consume more and more vegetation and often defoliate plants. To help hide the defoliated plants, you can grow non-host plants with host plants, so

Hornets (genus *Vespa*) and wasps (suborder Apocrita) are voracious predators and pollinators. As adults, they feed on nectar from flowers, while they feed meat to their young.

Mourning Cloaks (*Nymphalis antiopa*) are one of the earliest-flying butterflies. They overwinter as adults, usually tucked between peeling bark and tree trunks, and emerge when temperatures are warm enough. Providing logs with peeling bark is important for this species.

areas remain vegetated. The other vegetation also creates safer refuge for caterpillars to pupate and shed their skin between instars.

Where caterpillars pupate depends on the species, but providing the correct habitat for this stage is just as important as providing host plants. Many butterflies, like swallowtail (family Papilionidae) species, choose sticks and other surfaces in the shade—resources that are created by planting native plants. However, most moths and a variety of butterflies pupate in protected areas, including under loose soil, in leaf piles, between peeling bark and damp wood, and even under objects like stones and fallen branches. Make sure to research the life cycle of the target species and provide proper resources for their entire life cycle, especially safe areas to pupate like shade, loose soils, burrows, and microshelters. These areas can be located next to the host plants or up to 20 feet (6 m) away, but the farther away the area is, the harder it will be for the caterpillars to find. Reducing risks to butterflies and moths is also important. Lights can trap moths in areas and leave them exposed to predators as well as prevent them from mating. Pesticides kill caterpillars and pupa, so application should be avoided when possible. The following sections give broad overviews of different Lepidopteran groups and the resources they need to complete their life cycles.

— Geometer Moths

Inchworms, the larval form of geometer moths (family Geometridae), are common in gardens and are often seen at porch lights. The majority of species need loose soils, leaf litter, rocky ledges, downed branches, and even burrows for their pupating habitat. Providing these features and reducing light pollution and pesticide application, along with an array of native plants, are keys to promoting their populations. Research which species are common in your area to select preferred host plants.

MODEL BUTTERFLY

The taxonomic group Lepidoptera includes all butterflies and moths, most of which are common prey species for other animals, including birds, frogs, bats, robber flies (family Asilidae), and wheel bugs (genus *Arilus*), just to name a few. There are more than 14,000 species of butterflies and moths, from 75 families, in North America, and like many groups of insects, basic ecological data are lacking for most of them. However, a few species have been well studied. Monarchs (*Danaus plexippus*) are arguably one of the most well-studied butterflies and can be used as a model to understand risks each lepidopteran species faces.

As with most butterflies and moths, the Monarch life cycle includes eggs being laid on host plants. The caterpillar that emerges is known as the first instar. Butterflies and

The life cycle of the Monarch Butterfly (*Danaus plexippus*). Eggs (A) are laid on milkweed (genus *Asclepias*) and related genera. Larvae grow through five larval instars (B). Older instars tend to move from their host plant to shed their skins and will often climb onto new plants. When the larvae are fully grown, the caterpillar finds a safe place to spin some silk and forms a j-shape (C), sheds its skin, and turns into a chrysalis (D). When the butterfly emerges (E), it is known as an imago. It takes almost eight hours for the wings to fully expand and dry. When the butterfly is ready to fly it is an adult (F). Females will lay eggs singly on milkweed, but near the end of their life will lay multiple eggs on the same plant.

moths have multiple instars, and caterpillars must shed their skin between each stage. When caterpillars shed their skin, their exoskeleton is extremely soft, leaving them vulnerable to damage from predators as well as thorns and sticks swaying in the wind, so they must find shelter. This behavior is one of the reasons caterpillars seem to disappear on some days, only to reappear on others; it is also why it is important to have different plants mixed into garden beds. Similarly, when caterpillars are ready to pupate, they must find a sheltered place, out of the sun and with enough clearance to emerge and dry their wings. Monarch caterpillars have been found more than 100 feet (30 m) from their host plants, trying to find suitable places to pupate, which is a large energy cost and exposes them to many dangers. Most often, when caterpillars are seen crawling around away from their host plant, they are looking for a safe place to pupate or shed.

Each stage of every insect's life cycle has different natural enemies (predators, parasites, and parasitoids); some predatory species are a threat over the course of the lepidopteran's entire life. Some natural enemies, known as specialists, specifically feed on certain species, while others, known as generalists, have a broader diet. Since the ecology of Monarchs is so well studied, we can look at the natural enemies in their life cycle to better understand the threats other lepidopterans face, which life stages are most vulnerable, and what resources might improve their habitat.

Eggs are eaten by a number of insects, including other Monarch caterpillars, ants (family Formicidae), lacewings (family Neuroptera), and various smaller generalist species. First instars are susceptible to many of the same insects and also are susceptible to ingesting parasites like deadly fungal spores or the harmful neogregarine protozoan parasite *Ophryocystis elektroscirrha* (OE), which specializes on the Monarch genus, *Danaus*. Spores can be ingested during any instar stage, but infections tend to be more severe the earlier in life they are consumed. Other lepidopterans have their own parasites, some of which are species-specific, while other parasites target a broader range of hosts.

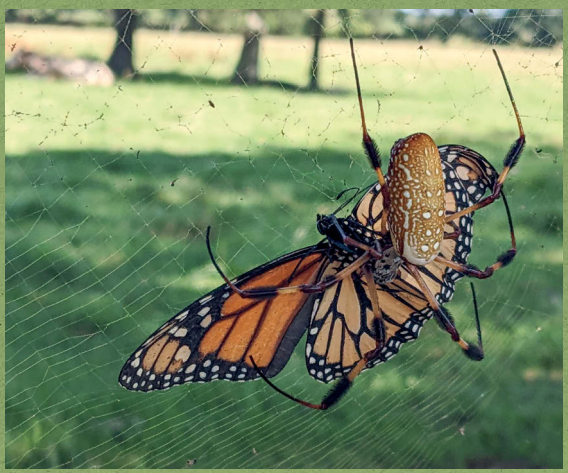
A fifth-instar Monarch (*Danaus plexippus*) caterpillar on Broadleaf Milkweed (*Asclepias latifolia*) with large frass (excrement) visible. In the wild, caterpillars regularly switch plants between molts, as evidenced by different-size frass and damage on plants.

continued overleaf

MODEL BUTTERFLY *continued*

As caterpillars develop and grow larger, larger predators can prey upon them. These predators include jumping spiders (family Salticidae), praying mantises (order Mantodea), Spined Soldier Bugs (*Podisus maculiventris*), umbrella wasps (genus *Polistes*), and wheel bugs (genus *Arilus*), as well as birds and rodents, which usually find the caterpillars unpalatable. Interestingly, both praying mantises and umbrella wasps have been observed carefully eating around the intestines where milkweed is still being digested, likely to avoid the poisonous chemicals the Monarchs sequester in order to be poisonous. Tachinid Flies (*Lespezia archipivora*) can also parasitize larvae and emerge in the fifth instar to pupal stage, killing their host. The lucky few caterpillars that make it through then must pupate. Pupae are susceptible to ants, mice, some insect predators, and the parasitoid wasp *Pteromalus cassotis*. These wasps produce hundreds of adults per chrysalis; they can infest local populations and show up year after year.

If pupation is successful, adult butterflies emerge, dry their wings in place (or nearby, if disturbed) for 8 to 24 hours. Some adults can have heavy OE infections, which they can spread to host plants and their own young, while others emerge healthy and start the cycle over again. As adults, these butterflies are still at risk from two bird species, large spiders, mantises, and collisions with vehicles. Monarch butterflies are different from most other species in that they have five to six generations a year; one generation is migratory and can live for many months. However, the overall threats and ecology can be applied to other lepidopterans to understand the risks they face. Using this understanding to assess gardens and habitats to reduce risks can help improve the survival rate and abundance of moths and butterflies.



A Monarch (*Danaus plexippus*) falls prey to a golden silk orb weaver (genus *Nephila*) in Louisiana.

ABOVE LEFT: Inchworms are caterpillars that move by extending their body flat, then forming an arch as they bring their pseudopod end toward their head. These are the larval form of the Geometridae family of moths. Pictured here is an unidentified inchworm trying to camouflage itself as a twig.

ABOVE RIGHT: An adult moth in the genus *Tarache* sits on a wall. The cutworm family of moths (Noctuidae) has a wide variety of shapes and can be very abundant at times.

— Owlet Moths

Cutworms, armyworms, and loopers are some of the more common larvae of owlet moths, members of the Noctuidae family. These insects are often seen as pests, but they are important food for many predacious animals. There are over 2,000 species in North America, with a wide variety of host plants, caterpillar sizes, and adult shapes. Successfully promoting species in this family means planting host plants, avoiding pesticide use, and providing loose soils, leaf litter, rocky ledges, and dead wood with thick bark for pupae to survive and overwinter.

— Nymphalidae

Members of the Nymphalidae, the largest family of butterflies, are known as brush-foot butterflies. Adults hold their front two legs next to their mouth, which makes

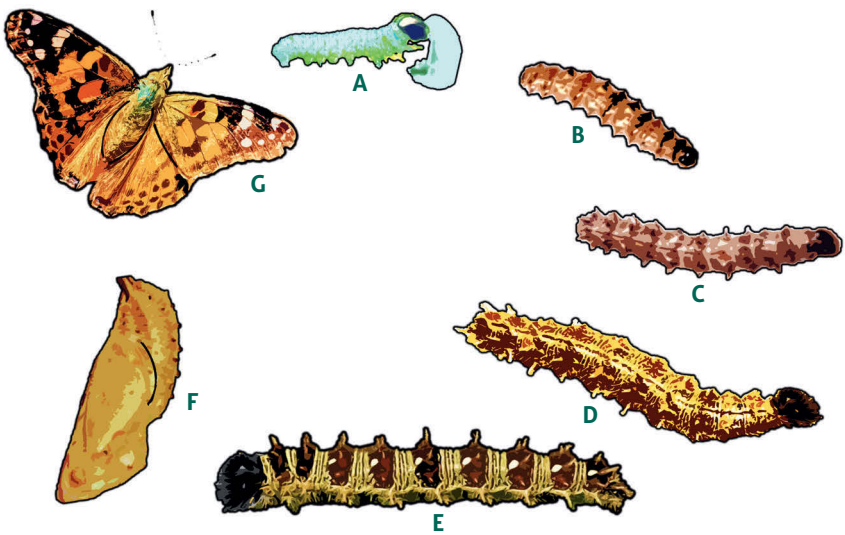
them appear to only have four legs. Many species have wide ranges; some common garden visitors migrate seasonally to occupy larger spaces in warmer months.

AMERICAN LADY

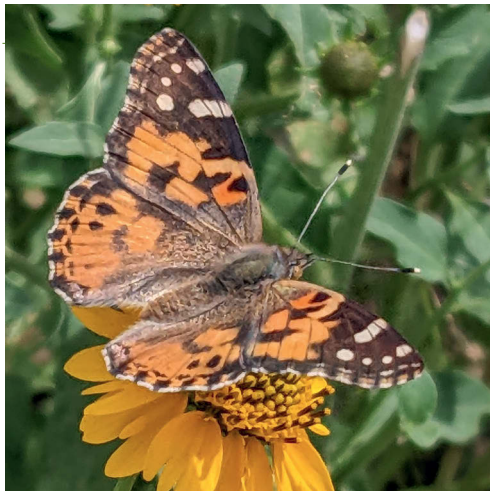
American Lady butterflies (*Vanessa virginiensis*) are in the same family (Nymphalidae) as Monarchs (*Danaus plexippus*) and Red Admirals (*V. atalanta*), both of which are known to migrate. Recent studies have documented that American Ladies also migrate and overwinter in the southern states, then migrate north in the spring. Their summer life cycle requires nectar sources for adults and host plants for larvae. Pupation can occur on host plants or in nearby areas.

Host plants for the American Lady include: Anise (*Pimpinella anisum*), Caribbean Purple Everlasting (*Gamochaeta antillana*), Cudweed (*Gnaphalium obtusifolium*), Icicle Plant (*Helichrysum thianschanicum*), Licorice Plant (*Helichrysum petiolare*), Pearly Everlasting (*Anaphalis margaritacea*), Pennsylvania Everlasting (*Gamochaeta pensylvanica*), Plantain-leaf Pussytoes (*Antennaria plantaginifolia*), Pussytoes (*Antennaria parlinii*), Silver Brocade (*Artemisia stelleriana*), Spoonleaf Purple Everlasting (*Gamochaeta purpurea*), and Sweet Everlasting (*Pseudognaphalium obtusifolium*),

An illustration of the life cycle of American Lady butterflies (*Vanessa virginiensis*), which have a wide range of host plants. Eggs (A) can hatch as quickly as in four days or take up to two weeks. Caterpillars grow quickly through five instars (A–E) in less than a month before pupating. Their chrysalis stage (F) lasts one to two weeks before an adult (G) emerges. Adults can travel thousands of miles in their short flight period.

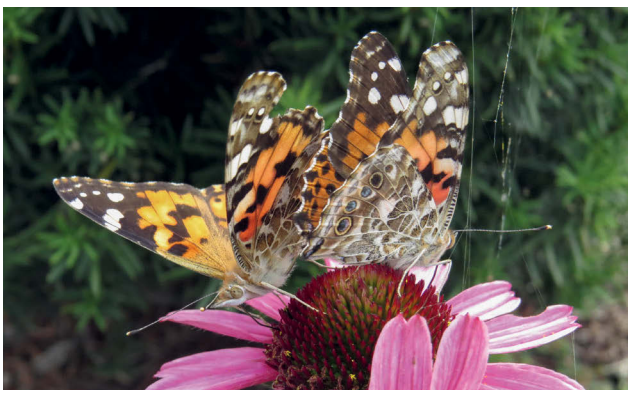


PAINTED LADY



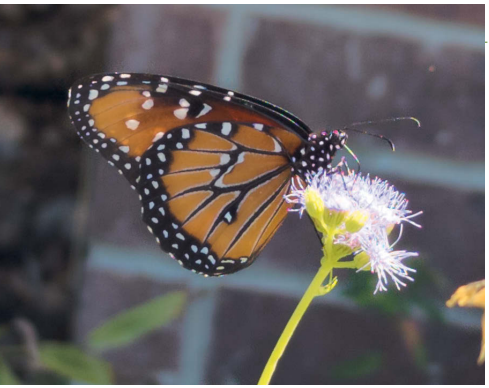
A migratory Painted Lady (*Vanessa cardui*) fuels up on a Cowpen Daisy (*Verbesina encelioides*) in early winter.

Painted Ladies (*Vanessa cardui*) occur throughout most of North America and are known to migrate, much like other butterflies in the Nymphaladie family. Eggs, which are pale green in color, are deposited singly on leaves of the many host plants (more than 100 plant species have been recorded). Host plants are primarily in the families Asteraceae (asters, daisies, and sunflowers), Boraginaceae (forget-me-nots), and Malvaceae (mallows), with some preference shown for marigolds (genus *Calendula*), hollyhocks (genus *Alcea*, which are not native), sunflowers (genus *Helianthus*), and thistles (including invasive Canada Thistle, *Cirsium arvense*, which is also a noxious weed in many states). Larvae hatch in three to five days and are grayish-brown or purplish-black with horizontal bands of yellow stripes and an array of soft protrusions and spiny hairs (scoli). Larvae can be found in silken nests at the tops of taller host plants, where they shelter throughout the day. Feeding occurs at night or on very overcast days. They develop quickly, in five to ten days, before pupating. Often a few caterpillars appear on a single plant and completely consume the vegetation. Chrysalises are formed by the caterpillar hanging upside-down, attached with a single silken string, on either the host plant or nearby vegetation. Adults emerge seven to ten days later and can live up to 20 days, producing more than 400 eggs.



Painted Lady butterflies (*Vanessa cardui*) feasting on a coneflower (genus *Echinacea*) bloom.

Encouraging these butterflies to visit a garden requires nectar plants. Host plants also promote the species, which should be spaced out and planted near other non-host plants.

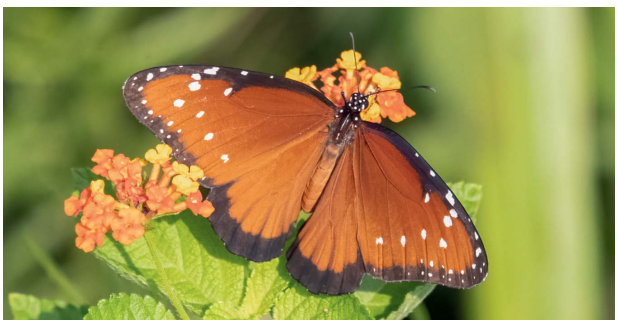


A Queen butterfly (*Danaus gilippus*) nectars on Palm-leaf Mistflower (*Conoclinium dissectum*). These plants and other members of the *Conoclinium* genus attract both Monarchs and Queens, making them perfect additions to butterfly gardens within the plant's native range.

MONARCHS AND QUEENS

Both Monarchs (*Danaus plexippus*) and Queens (*D. gilippus*) lay their eggs on milkweed species in the *Asclepias* genus. Monarchs also develop on a few closely related species, including the native Milkweed Vine (*Cynanchum laeve*), which is widely used in the fall in Oklahoma and Texas, and two non-natives: the Swan Plant (*Gomphocarpus physocarpus*) and the Blue Star (*Oxypetalum caeruleum*). Queens also develop on native species of twinevines (genus *Funastrum*). Both of these species are susceptible to the parasite *Ophryocystis elektroscirrha* (OE), so it is imperative to keep milkweeds healthy and remove old growth between generations. Caterpillars of both species are also susceptible to tachinid flies and have the same predators.

To encourage these butterflies in an urban environment, host plants should be planted and maintained. Short-term research on Monarchs suggests that planting host plants in abundance along garden borders increases larval density. However, it is not known how natural enemies respond to this planting design. Many milkweeds native to the Great Plains are fire-adapted and will regrow if they are trimmed back right after seeding. Broadleaf shrubs and tall bunchgrasses are recommended to be planted nearby as they create shelter for larvae to shed and pupate. Nectar-producing



A Queen butterfly (*Danaus gilippus*) on non-native lantana (genus *Lantana*).

flowering plants, including bonesets, gayfeathers (genus *Liatris*), goldenrods (genus *Solidago*), and mistflowers (genus *Conoclinium*), will attract feeding adults.

— Sulphurs, Whites, Yellows, and Other Members of Pieridae

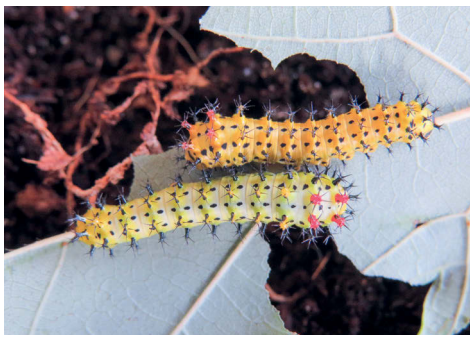
Sulphurs, whites, and yellows are all in the butterfly family Pieridae; over 140 species occur in North America, including some agricultural pests. Life cycles follow the typical succession of egg, caterpillar, pupa, and adult; some species overwinter as pupae attached to twigs and others as adults.

Promoting these butterflies in an area includes growing host plants and not removing vegetation from the property. Intentionally leaving host plants standing through winter will have the least impact on their survival. Adults are generalists and feed on most nectar-producing flowers. Check which species occur in your area to identify the best host plants for caterpillars. Risks include birds, spiders, ambush predators, and vehicles.

A Dainty Sulphur (*Nathalis iole*) on a wilting Showy Evening Primrose (*Oenothera speciosa*), where it has fallen prey to a flower crab spider (family Thomisidae). This is one of the smaller butterflies in North America and is regularly found in urban environments within their range.

— Saturniids

The lepidopteran family Saturniidae has mostly large and medium-size moths, including the largest species in North America. All species follow the typical life cycle but differ from most other lepidopterans in that adults cannot feed—they do not have a proboscis. The caterpillars therefore must consume enough food for the adult to have energy to find a mate and host plants, then lay eggs. Most species sew leaves together or spin cocoons in tight spaces near the ground or on trunks. You can encourage these species by leaving leaf litter, providing fallen logs, and including crevices for pupation as well as host plants.



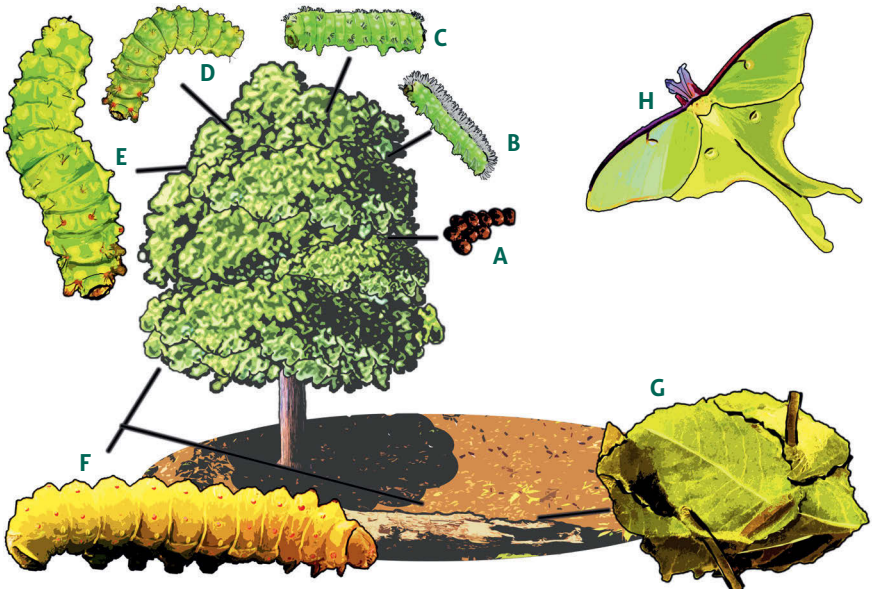
Two Cecropia Moth (*Hyalophora cecropia*) caterpillars on tree leaves. These larvae are rarely seen except in their final stage before they pupate, because they live in tree canopies.

An adult Cecropia Moth (*Hyalophora cecropia*) sheltering on a window during daylight. These short-lived moths are the largest moth species in North America and are disappearing due to pesticide use and leaf-fall removal.

LUNA MOTH

In the northern regions of their range, Luna Moths (*Actias luna*) have one generation a year, while two or three generations can be produced in the southern regions. Adults are unable to feed and therefore have very short flight periods of about a week and a half. In that time, females mate and can produce 200 to 400 eggs. In the wild,

Host plants of Luna Moths (*Actias luna*) include hickories (genus *Carya*), sweetgums (genus *Liquidambar*), walnuts (genus *Juglans*), and White Birch (*Betula papyrifera*). Eggs are deposited on tree leaves (A) and larvae (B–E) live up in the canopies. The fifth instar (F) crawls to the ground to pupate in secured leaf litter (G). Areas with leaf litter in gardens are key to their life cycle. Adults (H) emerge for a short flight season as they are unable to feed or drink.



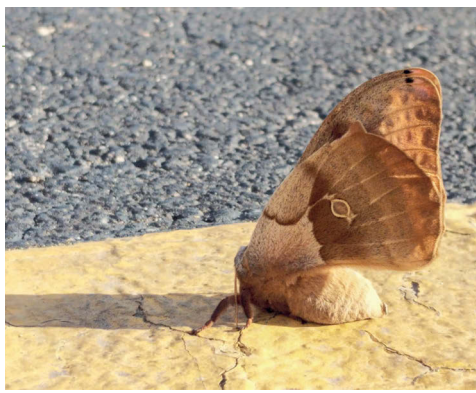
A Luna Moth (*Actias luna*) rests on a pot during the day in a garden actively trying to promote their populations.

eggs are preferentially laid on hickories (genus *Carya*), persimmon (genus *Diospyros*), Sweetgum (*Liquidambar styraciflua*), walnuts (genus *Juglans*), and White Birch (*Betula papyrifera*).

Eggs are generally laid in tree canopies, so seeing caterpillars is rare. Caterpillars have five instar stages before they pupate. Depending upon the season, caterpillar instar stages can range between four and ten days. These caterpillars are eating machines, which enables them to grow enough fat to survive as long as possible as adults. Their last act as a caterpillar is to make the journey from the tree canopy to the ground and find a safe area to pupate. Cocoons are spun in a collection of leaves, with summer generations in the South sometimes staying in trees or using leaf piles on the ground and emerging in roughly two weeks. Overwintering generations always pupate in leaves on the ground and may remain in their cocoons for up to nine months. This long overwintering stage is dependent on leaf piles remaining in place. To encourage Luna Moths in an area, make sure to plant a host tree, reduce light pollution, which can trap adults and prevent them from breeding, and leave leaf piles in place.

POLYPHEMUS MOTH

The Polyphemus Moth (*Antheraea polyphemus*) lays eggs on a variety of host tree species, including American Elm (*Ulmus americana*), birches (genus *Betula*), and willows (genus *Salix*). In rare cases, larvae have also been found on other



A Polyphemus Moth (*Antheraea polyphemus*) sits in a parking lot under a streetlight in the early morning. Certain lights attract these moths and trap them in areas where they cannot reproduce.

tree species, including hickories (genus *Carya*), maples (genus *Acer*), pears (genus *Pyrus*), plums (genus *Prunus*), oaks (genus *Quercus*), and walnuts (genus *Juglans*). Caterpillars go through five larval stages, each quite different in appearance from the last. The fifth instar is green, reaching up to 4 inches (10 cm) in length. At the end of the fifth-instar stage, the caterpillar spins a cocoon on the host tree, sewing leaves together and tethering itself securely to a branch. Encouraging this species is best done by planting one of the preferred host trees and turning out lights that can attract and trap adults.

A hummingbird clearwing moth (genus *Hemaris*) visits long, tubular flowers. It is important to consider the shape of blooms when selecting plants for pollinators.

— Hummingbird and Sphinx Moths

Regular early arrivals in new gardens are adult hummingbird moths and sphinx moths (family Sphingidae), with roughly 140 species in North America. This is partially due to their ability to fly quickly and cover long distances, as they search for nectar and host plants, and their ability to survive in urban environments. Depending on where you live, daytime species might be common, but throughout North America, evening and nighttime flyers can be abundant. Floral resources for most species include evening primroses (genus *Oenothera*), long-tubed flowers like bee balms (genus *Monarda*), members of the phlox family (Polemoniaceae) and the verbena family (Verbenaceae), as well as open flowers, like those found in the Asteraceae family (asters, daisies, and sunflowers). Most species in this family produce large pupae that form after the caterpillar buries itself in soft soils, leaf litter, or soft, decaying wood. Creating habitat that supports their entire life cycle includes planting host plants for caterpillars, providing suitable spaces for pupating, and growing nectar-producing flowers. Check to see which species are native to your region to narrow down host plants and pupal habitats.

WHITE-LINED SPHINX

A delight to be seen as an adult by many gardeners, White-lined Sphinx moths (*Hyles lineata*) are often seen at dusk visiting an assortment of flowers. The larvae of this moth, however, are the bane of many tomato-growing gardeners, even though they are not the Tomato Hornworm (*Manduca quinquemaculatus*), both of which can devastate plants. Caterpillars of this species feed on an incredible diversity of species,

ABOVE LEFT: A White-lined Sphinx moth (*Hyles lineata*) crawls into the flower of a Bush Morning Glory (*Ipomoea leptophylla*) to rest.

ABOVE RIGHT: A moth in the family Sphingidae, with more nocturnal behaviors but a similar life cycle and needs as compared with White-lined Sphinx moths (*Hyles lineata*).

including Sand Verbenas (*Abronia umbellate*), Brown-eyed Evening Primrose (*Camissonia claviformis*), Bee Plant (*Gaura lindheimeri*), apple trees (genus *Malus*), four-o'clocks (genus *Mirabilis*), evening primrose (genus *Oenothera*), nightshades (genus *Solanum*), and grapevines (genus *Vitis*). Their voracious appetites can decimate and defoliate plants quickly before they begin searching for a place to pupate.

Like many members of Sphingidae, in order to pupate, the caterpillars burrow into loose, soft soils that are under leaf layers or objects. Larvae bury 1 to 7 inches (2.5–17.5 cm) deep and form chrysalises. Often, gardeners find the pupae when digging in garden beds. When a pupa is disturbed, it can be placed back where it was and covered by loose soil. If the pupa needs to be relocated, preferred areas tend to be damp, well-drained soils with some cover, including low-growing plants, leaf piles, logs, and stones.

Amphibians

— Frogs

CHORUS FROGS

There are currently 19 recognized species of chorus frog (genus *Pseudacris*) in North America, but the taxonomy will likely change with more genetic data. On the West

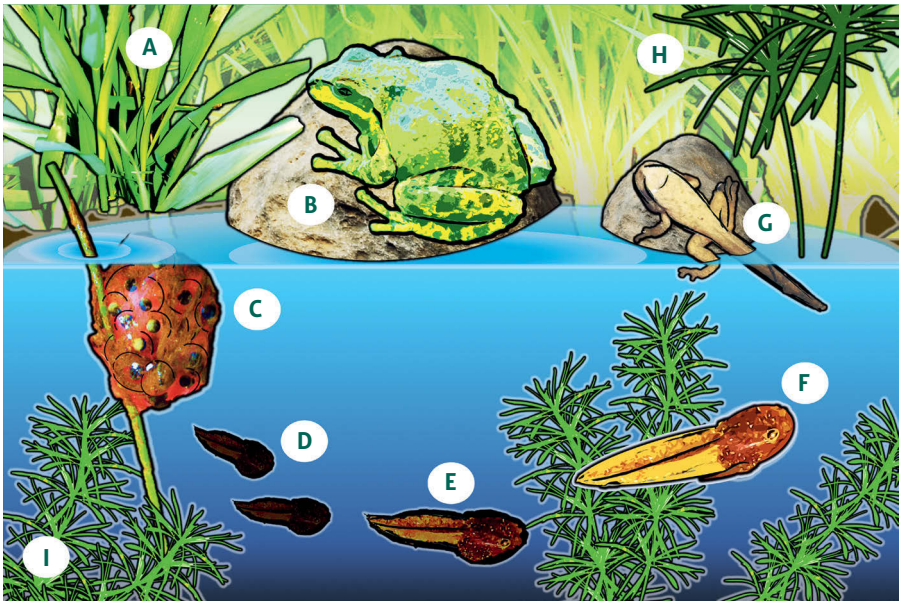
ABOVE LEFT: A chorus frog (genus *Pseudacris)* sits among leaf litter and mosses, where this species often hunts.

ABOVE RIGHT: A Gray Tree Frog (*Dryophytes versicolor*) nestled down on a smooth surface. Many species of tree frogs (suborder Neobatrachia) and chorus frogs (genus *Pseudacris)* can be found sleeping on smooth surfaces like the pictured metal bar or PVC pipes and even windows.

Coast, there are three common species; in the South, there are eight common species; and in the Northeast, there are three common species, including the Spring Peeper (*P. crucifer*), which is more common near the ground and along wetlands.

Chorus frogs generally breed in late winter and early spring. Their tadpoles are fairly small and fall prey to many fish and arthropods, including dragonfly larvae and predaceous diving beetles. In order to create robust habitat for these frogs, install water catchments that can hold water through the winter and spring and that also provide cover for tadpoles to seek shelter. Near houses, chorus frogs regularly lay their eggs in buckets and trash cans that fill with water, but these containers can quickly become inhospitable. To better manage these spaces when they become unintentional breeding ponds, move the entire container to dappled shade to prevent overheating. Keep containers full by adding rainwater or purified water and place a small floating object like dry wood or Styrofoam for froglets to rest on and breathe air. If the container has too many tadpoles, a secondary container can be filled with half of the water and tadpoles from the original pool. These should slowly be filled with rainwater to allow the tadpoles to adjust to changing temperatures and water chemistry. If algal growth is not sufficient, they will turn to cannibalism. Fresh lettuce or rinsed dry seaweed work as food supplements but can foul the water. Make sure to monitor water conditions and clean the water catchments as needed.

Adults of most species can be found resting on broadleaf plants, clinging to outside walls, and resting on damp tree bark and inside pots. They prefer damp, shaded



An illustration of the chorus frog (genus *Pseudacris*) life cycle with key habitat resources. (A) Nearby vegetation provides shelter for frogs as they call. (B) A mature adult frog that can mate. (C) Mass of eggs laid on emergent vegetation. Frogs lay eggs in masses, while toads lay eggs in strands. (D) Recently hatched tadpoles tend to be dark in color. (E) As tadpoles develop, they tend to lighten in color, and hind legs begin to form. (F) Mature tadpole before growing front legs. (G) The transition morph from tadpole to froglet; the tail is absorbed, and the frog's terrestrial stage begins. (H) Emergent vegetation provides below-surface structure for tadpoles and aerial structure and shelter for froglets. (I) Aquatic vegetation aerates the water, provides structure, and increases foraging surfaces for tadpoles.

places to rest during the day and for hunting at night. You can promote these species by placing soaking dishes near sheltering areas, encouraging nocturnal insect populations, and providing sufficient breeding locations. Most species also gladly adopt wide, vertical PVC pipes in shady, damp areas for their sleeping spots.

GREEN FROGS

Green Frogs (*Lithobates clamitans*) commonly live in urban areas that also have suitable habitat, making them fairly easy to attract to gardens. Preferred habitats have high soil moisture, fine woody debris, sparse tree coverage areas with little to no vegetation at ground level, and open water. Their name comes from their typically green head, although there is a bronze subspecies, and some frogs have more muted colors than others, with brown bodies and lighter coloration on their chest and belly. Males

A Green Frog (*Lithobates clamitans*) sits in a prefabricated, shaped pond.

use four different breeding calls, which can be heard most often in spring and summer.

Green Frogs typically breed in shallow areas of permanent bodies of water, including roadside ditches, ponds, and slow-moving streams with submerged vegetation. Eggs are laid in large masses (1,000–7,000 eggs) in surface films anchored to vegetation. Clusters of eggs can be 6 to 12 inches (15–30 cm) in diameter. Tadpoles typically hatch within three to six days. Depending on the location and time of year at which eggs are laid, larvae can develop within 70 days or take almost a full year.

The adult diet is mostly moths and snails, but they are known to try to eat any animal that will fit in their mouth, including crayfish, other amphibians, and small fish and reptiles. Tadpoles feed mostly on algae and diatoms, but also eat protozoans and microcrustaceans.

To create habitat for these frogs in a garden, choose an area that has consistently wet soils. Males set up territories in water bodies, so installation of a perennial body of water is necessary. Unfortunately, there are no data for the smallest pond size Green Frogs will inhabit. However, researchers in Canada built ponds with a surface area of 118 to 183 square feet (11–17 m^2) and 1.5 feet (0.5 m) deep and successfully recruited Green Frogs from nearby areas. So, we know frogs will accept a pond that is 7.2 by 16.5 feet (2.2 × 5 m) and 1.5 feet (0.5 m) deep, but they may go smaller. Since adult frogs prefer deeper water to escape into, ponds should have areas at least a foot (30 cm) deep with shelters to hide in. Place a large log or two near the pond, and install a mulch pit to help attract sufficient food resources to that area as well.

A small brook and garden design in New York. Similar designs filled with native plants and calmer pools make good habitats for Green Frogs (*Lithobates clamitans*).

SQUIRREL TREE FROG

A group of *Hyla* species tree frogs spending the day in a PVC pipe in Alabama. A regular sampling method for tree frogs includes placing wide-diameter PVC in damp, shaded areas. The same setup can be used in gardens to keep frogs safe from accidental encounters.

A common sight at porchlights in the South, Squirrel Tree Frogs (*Dryophytes squirellus*) are active, nocturnal predators of insects. Hunting grounds include compost piles, dung piles, lights, and other spaces that attract insects. During warmer nights, they can be abundant in urban areas that have perennially damp areas. In winter, groups of adults huddle together under bark and in tree trunks or fallen logs to survive cold temperatures.

After rain events, Squirrel Tree Frogs return to fishless water bodies to breed. Typical locations include ephemeral pools, roadside catchments, and pools of water in tree canopies. Tadpoles feed on organic matter and slime layers that grow on hard surfaces like submerged rocks, logs, and plants. You can encourage Squirrel Tree Frogs by supporting all the microhabitats they need throughout the year. This includes providing short-term bodies of water for tadpoles and damp terrestrial areas for adults, both of which are threatened by increasingly dry periods driven by climate change. Adding compost piles and promoting nocturnal insects will increase prey abundance, while installing hollow logs and underground dens will offer sufficient overwintering sites.

— Salamanders and Newts

BARRED TIGER SALAMANDERS

A large, unidentified salamander crawling through a mowed area.

Found throughout the western Great Plains, Rocky Mountains, and parts of Washington and California, Barred Tiger Salamanders (*Ambystoma mavortium*) often lose habitat to urban sprawl. Their range includes five recognized subspecies, all of which occupy similar habitats. Adults typically range in size from 6 to 10 inches (15–25 cm) and exhibit beautiful dark and light coloration patterns. Folks most often encounter adults at night after

rainstorms, when they venture farther from their damp hunting grounds and shelters. Typically, these large salamanders take refuge in rodent burrows, but they have also been found in loose soils, where they excavate their own tunnels. One of the reasons these animals are so susceptible to urban sprawl is that the adults require damp areas, typically with lots of organic matter like dead leaves and decomposing logs, while their larvae, known as mudpuppies, require clean, fishless water bodies that hold water for three to five months at a time. Larval forms feed on clam shrimp ostracods (family Cyprididae), water boatmen (family Corixidae), tadpole shrimps (family Triopsidae), and fairy shrimps (family Streptocephalidae). In drier ecoregions, cannibalistic larvae are common; they have teeth and tend to turn into adults faster than typical larvae.

Creating habitat for these gorgeous creatures requires providing space for both larvae and adults. Loose, organic layers under shrubs and trees and between dense herbaceous plantings provide decent hunting grounds for adults. Large logs, rocks, and even hay bales placed on top of loose sandy soils, and installed burrows that stay damp—but not flooded—will provide sufficient shelter in both summer and winter. Barred Tiger Salamander adults feed on a wide variety of prey, including slugs, worms, grubs, crickets, and cockroaches, which do well in loose organic layers. Larval habitat can include perennial ponds, but the larvae will quickly be eaten if fish or crayfish are present. Both temporary and perennial water bodies should be 9 inches (23 cm) or more deep and a minimum of 4 feet (1.2 m) in diameter, although larger is better. Data on preferred aquatic habitat size are lacking for many amphibian species; however, simply replicating natural designs should provide sufficient prey.

EASTERN NEWT

Eastern Newts (*Notophthalmus viridescens*) are between 2.5 and 5 inches (7–12.5 cm) long and have yellow bellies with black spots; their backs vary from yellowish-brown to dark brown, smattered with small, black-ringed red spots. Animals can live up to 15 years but are susceptible to habitat loss and urban expansion. Their skin is loose

A red-eft form of the Eastern Newt (*Notophthalmus viridescens*), found sheltering under stones near a creek, in New York.

and rough to the touch and needs to be kept moist, which keeps them restricted to damp areas throughout the eastern part of North America. Larvae and aquatic adults can be found in small areas of freshwater, including stream pools, vegetated lakes, marshes, and ponds. Terrestrial juveniles and adults can be found in wet leaf litter, as well as under stones, rotting logs, and peeling bark.

Habitat requirements for Eastern Newts include year-round moisture in leaf litter and logs, as well as, starting in later winter, a standing body of water that lasts a minimum of three and a half months. In winter, Eastern Newts can be found in rodent holes, deteriorating wood, and loose piles of organic material. During dry seasons, they can be found under leaf litter, fallen logs, stones, and other damp objects. In late winter to early spring, a single female deposits between 200 and 350 eggs, which take three to five weeks to hatch, depending on temperature. Larva need two to five months to develop before morphing into a terrestrial eft. Efts are bright orange with spots and mature into adults in two to three years. Most populations develop into aquatic adults, which need year-round water resources, but in some populations, adults remain terrestrial except to mate. There are also a few reports of some adults remaining in an aquatic state their entire lives and keeping their gills, which may happen if your garden has a large, healthy pond ecosystem.

Encouraging Eastern Newts to live in a garden is best done by adding perennial, fishless habitats near large-canopy trees. Gardeners have reported these newts living in areas made with large, premade pond liners, but larger aquatic habitats are better. The trees provide leaf litter for juveniles and adults to forage in. Larva and adults consume invertebrates, including mosquitoes, fly larvae, and worms, which should be present in the pond and leaf litter. Adding deep crevices and burrow-like shelters, mulch pits, and fallen logs to the landscape will provide adequate shelter throughout the year. Areas can be landscaped to include plants and habitat resources for other target wildlife as well.

A Rough-skinned Newt (*Taricha granulosa*), found on the Northwest coast, inhabits similar niches as the Eastern Newt (*Notophthalmus viridescens*) and can be encouraged with the same abiotic features.

A California Slender Salamander (*Batrachoseps attenuatus*) crawls on leaf litter below a Coastal Redwood (*Sequoia sempervirens*) after being disturbed when children's toys were moved.

SLENDER SALAMANDERS

Most species of slender salamanders (genus *Batrachoseps*) are active on rainy or wet nights when temperatures are moderate, from autumn through spring; they retreat underground when the soil dries or when the air temperature drops to near freezing. Populations do best when there is a permanently damp refuge, like a late-stage decaying log or deep leaf litter under a well-irrigated tree.

Most surface activity for this species has been observed from February to early April. Unlike many other amphibians, larvae of slender salamanders develop completely in the egg, which is laid in damp soils or organic matter. Once they hatch, they are fully formed, miniature adults. Juvenile salamanders are rarely found, which suggests that they hatch underground at the end of the wet season and feed underground during the beginning of their lives.

You can create habitat for this species by adding burrows and deep-crevice, rocky shelters in cool, shaded, wet areas. Areas should also have permanent leaf litter in varying stages of breakdown and mulch pits to promote prey species. Native shade-tolerant plants can be added to the landscape to diversify habitat structure and support other wildlife.

A prime habitat for slender salamanders (genus *Batrachoseps*) mimics old tree falls, like this large branch in Seattle, Washington. Pits of damp mulch, old logs, and stumps in a shady, leaf-fall area can provide suitable habitat for these adorable wildlife.

EASTERN RED-BACKED SALAMANDER

A mature Eastern Red-backed Salamander (*Plethodon cinereus*) crawling on forest leaf litter after a few days of rain in Connecticut.

Eastern Red-backed Salamanders (*Plethodon cinereus*) are slender salamanders, so they do not have an aquatic larval stage. Instead, eggs are deposited in damp wood, where the larvae develop and emerge able to live on land. They are the most common salamander in their range and inhabit areas under rocks, logs, bark, and other debris in forested areas. Encouraging their populations in gardens requires shelters under rocks and logs, with damp soils. Their prey can be promoted by leaving leaves and other organic matter in areas that are kept damp. Adding areas of buried mulch or deep burrows will provide overwintering shelters.

— Toads

AMERICAN TOAD

A juvenile American Toad (*Anaxyrus americanus*) soaks in a small depression on a garden bed rock wall after irrigation, in Pennsylvania. Small features, like areas that hold water for a few hours, are important for urban wildlife.

American Toads (*Anaxyrus americanus*) were once abundant throughout the eastern half of North America, but their populations have suffered from habitat loss, agriculture, and urban expansion. Adults can be found hunting around forests and wooded neighborhoods and are often buried below the soils in recently planted garden beds. They prefer soft soils, late-stage decaying wood, and deep leaf litter to bury themselves in, as well as other hiding places. After rains, their high trill calls can be heard from pools, ditches, and perennial ponds, where they can lay between 1,500 and 20,000 eggs each. Tadpoles can take up to two months to develop before turning into their terrestrial form. Toadlets usually search for shaded areas in upland forests near their natal pools. There they hunt small arthropods, including small grubs, ants, flies, spiders, slugs, and worms. Damp leaf litter, organic-rich soils, microshelters, crevices, and burrows help the young shelter and overwinter.

You can promote American Toads (as well as many other species of toads) in an area by providing damp, shaded areas with leaf litter, organic-rich soils, and ample shelter, including deep burrows for overwintering. Landscaping the area with plants that provide cover and support many insects will also improve local habitats. Where possible, provide ground-level soaking areas, like shallow dishes and rocks with concave surfaces, to help adults hydrate. Similarly, you can install breeding pools that hold water either for a few months or all year to help with their overall life cycle.

Reptiles

An Eastern Side-blotched Lizard (*Uta stansburiana*) juvenile hangs out near a cattle guard in the Permian Basin, in Texas.

— COMMON SIDE-BLOTCHED LIZARD

Within their range, Common Side-blotched Lizards (*Uta stansburiana elegans*) can be locally abundant in suburban areas. However, these lizards quickly disappear in lawn-dominated neighborhoods that lack rocky areas, retaining walls, or good shelter. Female side-blotched lizards lay between two and nine eggs per nest, averaging around five eggs. Nests are excavated by females in dry areas with loose, sandy soils and tend to be placed under large objects on the surface, including stepping-stones and fence boards. Males are known for their territorial displays; they perform one or more "pushups" with their side to the intruder (including humans). They will also arch their backs and extend their limbs.

To encourage these lizards in the landscape, make sure to include rockscapes, microshelters, crevices, and burrows. Sandy soils beneath objects provide suitable nesting sites, and soaking dishes or ground-level watering stations help them stay hydrated. Their diet consists of mostly insects and other arthropods, which can be promoted with native plants and reduced use of pesticides. Neighborhood cats are also a huge risk to these lizards and should be kept away.

— GREEN ANOLE

Green Anoles (*Anolis carolinensis*) are native to the Gulf Coast and the southern East Coast, but have been introduced to other areas; they have also expanded their

ranges with urban development. Within their range, the invasive Brown Anole (*Anolis sagrei*) often outcompetes them in suburban areas, especially in areas without taller vegetation. Both species can change colors between brown and green, although Green Anoles are more brilliant.

You can encourage Green Anole populations by providing broadleaf plants, vertical structures, and sandy soils for nesting. Shallow watering stations can be installed a few feet off the ground near plants to promote hydration. Reducing use of pesticides increases prey populations.

A Green Anole (*Anolis carolinensis*) sits in a vine of the genus *Smilax*.

— LITTLE BROWN SKINK

Found throughout the eastern half of the United States and limited forested areas of Mexico, the Little Brown Skink (*Scincella lateralis*) is a small, forest-loving, suburban-adapted lizard. Gardeners often find them rummaging through leaf litter, under logs, and around pots and rocks. Unlike most lizard species, these adorable reptiles prefer forested areas, including woodlots, neighborhoods with numerous trees, and natural areas. Their home ranges can be smaller than typical front yards in mostly upland areas but can include stream banks and wet areas.

A Little Brown Skink (*Scincella lateralis*) scurries across a driveway between garden beds with leaf litter and rock walls, in Corpus Christi, Texas.

To promote this species, provide large areas with deep, loose, organic layers like leaf litter and mulch under trees or around the shady sides of buildings. Their diet is comprised of small arthropods, so avoiding pesticide application near their habitat will keep them well fed. Shelters include microshelters, crevices, areas between shedding bark and logs, and other animals' burrows. Eggs are laid in damp, decaying wood and sandy soils, which should be included in the landscape near their habitat. Little Brown Skinks overwinter and need an underground refuge that will not freeze or get too wet.

An alligator lizard (genus *Elgaria*) illustrated in its preferred habitat with leaf litter, logs, stones, and suitable soils for nesting.

— ALLIGATOR LIZARDS

Alligator lizards (genus *Elgaria*) are found on the West Coast from Mexico to Canada and are common in suburban neighborhoods. Most often, they can be found in well-vegetated areas, taking refuge under stones and dry logs, but they also bask near dusk in small sunny spots. All species are predatory, typically feasting on insects and spiders, but they will also take small vertebrates like froglets when available. Studies that looked at alligator lizard ranges in the northern extent of their range showed that, throughout the year, they did not cover a large area but stayed within a few hundred square feet. This suggests that nesting sites and hibernation areas are in the same local vicinity. Data collected for populations in the center of their range show that alligator lizards migrate to local hibernation dens, then disperse in late spring.

Most populations lay eggs, with clutches ranging between 5 and 20 eggs, which are typically laid in late spring to midsummer (May–July). However, some populations in the damp Northwest are viviparous; they carry the eggs internally until they hatch and give birth to live lizards. Nests are located in crevices between rocks and inside rodent burrows. Gestation of the eggs takes about 11 weeks, and these lizards can live up to 15 years.

You can create habitat in gardens for species in this genus by placing large rocks in well-vegetated areas. Make sure some of the stones are stable and lifted off the soil or have excavated areas where lizards can find refuge. Similarly, larger stones with flat sides can be buried into the ground, with sandy soils surrounding them to create crevices for lizards to lay eggs. Adding logs and dry burrows also helps create winter hibernacula and potential nesting sites.

— COMMON AND ORNATE BOX TURTLES

All species of box turtles in North America are quickly declining in abundance across their range due to habitat loss, roads, increased mortality risks, habitat fragmentation, and illegal collecting. Common Box Turtles (*Terrapene carolina*) range from southern Canada, south to Florida, and into the Great Plains. Ornate Box Turtles (*Terrapene ornata ornata*) have a more southern and western distribution, extending from South Dakota to Mexico, and from Arizona to Wisconsin. All species overwinter underground and cannot tolerate freezing. They lay eggs in shallow nests that females

excavate in sandy to loamy soils. Box turtles have home ranges, can live a few decades, up to 50 years, and prefer access to shallow water for hydrating and hunting.

An Ornate Box Turtle (*Terrapene ornata ornata*) moves across a mowed area within its home range

Common Box Turtle nests are shallow, reaching 1 to 3 inches (2.5–7.5 cm) deep and covered with soil and leaf litter. It takes 70 to 80 days for the eggs to hatch. Hatchlings may stay in the nest until the following spring, or they may emerge and find another place to hibernate with adults. Overwintering sites have been described from areas with sandier soils, leaf litter, detritus, and bare ground, and an absence of shrubs and ground covers. Neither the eggs nor the turtles tolerate freezing, so microhabitats must provide enough insulation from winter temperatures. Data are lacking on whether these turtles benefit from large mammal burrows, but young seek shelter in any underground opening they can access in summer heat.

Males of Ornate Box Turtles have home ranges of, on average, 250–450 feet (76–137 m), which is about 35 feet (11 m) larger than females, both of which can easily fit in suburban areas. Females in the Great Plains have been observed excavating nests 6 to 7 inches (16.2–17.5 cm) deep in sandy to sandy loam soils.

Both Common Box Turtles and Ornate Box Turtles are omnivorous, feeding on small vertebrates, including recently deceased carrion, as well as land snails, beetles, stick insects, and a variety of plants. Mulberries (genus *Morus*), persimmon (genus *Diospyros*), prickly pears (genus *Opuntia*), and other fleshy fruits are sought

A box turtle (genus *Terrapene*) in Oklahoma moving about its home range.

after by adults. Promoting either species includes providing burrows and dens for them to escape summer heat, landscaping with fleshy, fruit-producing plants and preferred vegetation, and installing standing shallow water to wade, soak, drink, and hunt in. Areas of dry, loose sandy soils with leaf litter can also be added to landscapes to provide nesting sites.

An illustration of the Ringneck Snake (*Diadophis punctatus*); it has a bright red underbelly and uses damp logs as a common hideout.

— RINGNECK SNAKE

Ringneck Snakes (*Diadophis punctatus*), one of the most wide-ranging snake species in North America, are rather secretive and often overlooked. These snakes are commonly handled by curious children and adults because they have a nonaggressive disposition, they're small, and they pose little threat with their rear-facing fangs. Typically, they live in wooded areas and hunt at night. They prey on other small vertebrates, including amphibians, lizards, and other small snakes, as well as arthropods like worms, crickets, and snails. Female snakes seek out damp, decaying logs to lay eggs. Clutch sizes are usually small, with fewer than 10 eggs. To encourage this species in an area, provide ample leaf litter, habitat for snails and crickets, old wood, areas of loose soil, and narrow crevices for them to seek shelter.

A foraging snake moves through leaf litter.

— DE KAY'S BROWN SNAKE

A frequent inhabitant of urban and suburban areas in the eastern part of the continent, De Kay's Brown Snakes (*Storeria dekayi*) are often found in yards. Most commonly, they are found in irrigated and wetter areas of gardens with sufficient leaf litter or plant cover. When they are hiding, these adorable snakes can be found under rocks or logs with soft footings (space underneath). If soils are loose, De Kay's Brown Snakes also burrow. In colder regions, these snakes likely hibernate underground, under either house slabs or decaying root structures that stay above freezing.

Soon after emerging from their overwinter sites, these snakes begin reproducing. They do not lay eggs but give birth to live young. Adults are active throughout

most of the growing season. Their main diet staples are slugs, snails, and earthworms. These snakes are commonly preyed upon by larger animals, including frogs, birds, and lizards.

To encourage these harmless garden helpers to take up residence, make sure to include stones and logs in your garden designs. Make sure to put down a thin layer of mulch or gravel to keep space between the soil and the sheltering surface.

Birds

Songbirds are one of the most common groups of wildlife folks try to attract to their yards. Surveys conducted in a few mid-income, suburban neighborhoods showed more than 50% of the homes put food out for birds. Although feeders attract some birds, creating great habitat for our feathered friends requires an understanding of their ecology, seasonal needs, and life history. Attracting birds to an area can involve simply providing temporary shelter and perches, placing a birdbath, hanging a feeder, or intentionally growing food for both adults and chicks. Numerous articles explain which plants benefit adult birds, especially in winter and during migration. However, most folks do not realize that most songbirds require protein from insects, worms, and other arthropods when they are young. This includes bird species that feed on seeds and fruits as adults. (The major exception is pigeons and doves, which are fed regurgitated seeds.) The best way to create habitat for birds in your yard is to promote insects, especially caterpillars, grasshoppers, beetle grubs, and crickets. Providing food for these insects while also avoiding widespread application of pesticides helps adults feed their young and improves the likelihood they will reach adulthood.

Including native plants in garden designs provides more forage for native insects and therefore more insects for birds (again as long as widespread use of pesticides is

A Dickcissel (*Spiza americana*) sings from a barbed-wire fence.

A Townsend's Solitaire (*Myadestes townsendi*) nests in the crevice of a decaying retaining wall. Many wildlife find useful resources in developed spaces that were not intended for their use. Often, this puts wildlife at higher risk of injury and harassment.

also avoided). Some native plant genera that are good for prey insects are oaks (genus *Quercus*), cherries and plums (genus *Prunus*), and a variety of herbaceous flowers and grasses. You can also refer to Dr. Doug Tallamy's Lepidoptera Index for plant suggestions, which mostly focuses on plants from the northeastern United States. You can encourage grasshoppers and caterpillars in ecoregions with large grasslands or savannahs by growing palatable plants like Honey Mesquite (*Neltuma glandulosa*), evening primroses (genus *Oenothera*), and Switchgrass (*Panicum virgatum*).

Seeds and fruits of plants are also important for attracting birds because they are common forage. Plants that produce fleshy fruits, like berries, or lots of seeds, like sunflowers, coneflowers, and various grasses, also attract birds and feed a variety of insects. When possible, grow an array of plant species that produce fruits in different

An American Goldfinch (*Spinus tristis*) feeding on seeds of native plants in the garden. Planting native Common Sunflowers (*Helianthus annuus*) and coneflowers (genus *Echinacea*, genus *Rudbeckia*) often attracts American Goldfinches to an area.

seasons. For example, Agarita (*Berberis trifoliata*) and blueberries (genus *Vaccinium*) produce berries in late spring; many species of prickly pear (genus *Opuntia*) produce berries part of the year, depending on rain patterns; and various holly species (genus *Ilex*) produce fruits late into winter. Similarly, windmill grasses (genus *Chloris*), bristlegrasses (genus *Setaria*), coneflowers (genus *Rudbeckia* and genus *Echinacea*), and native sunflowers (genus *Helianthus*) produce seed from late spring through late fall.

— Birdhouses and Shelters

Many areas around your home can be improved for birds by providing necessary shelter resources. Some examples include placing owl boxes on roofs and in large trees, installing bluebird houses on fence posts, and hanging nest platforms for doves and robins in trees and shrubs, and under roof overhangs. Knowing where local species nest is critical to creating good nesting habitat for the birds. Some bird species, like Eastern Bluebirds (*Sialia sialis*) nest in cavities, including birdhouses and tree hollows, while Cactus Wrens (*Campylorhynchus brunneicapillus*), Song Sparrows (*Melospiza melodia*), and Northern Mockingbirds (*Mimus polyglottos*) construct nests in low shrubs. Some species of birds prefer to nest in tall trees, while other species nest near the ground or in unconventional spaces often found around buildings.

In wild settings, hollow spaces used by cavity nesters are created by insects, fungal rot of limbs, and woodpeckers. As discussed earlier, dead wood and sick trees are typically removed from urban areas, which has reduced populations of many cavity-nesting birds that would otherwise do all right in developed areas. Luckily, we can quickly bring these resources into our yards, either with constructed birdhouses or by securing hollow branches onto trees and posts.

A pair of Eastern Bluebirds (*Sialia sialis*) outside a natural cavity where they are building their nest. The scarcity of hollows in agricultural areas has been successfully addressed in many places with the addition of bluebird houses.

A Black-chinned Hummingbird (*Archilochus alexandri*) sits on its nest among thin branches. Hummingbirds weave lichens, spider silk, and organic matter into tiny nests. These resources differ between species, but each resource should be cultivated when creating habitat for hummingbirds.

A living oak tree (genus *Quercus*) with a hollow branch. Live trees can lose interior wood that is not alive and thus provide shelter for many species. Birdhouses replicate these hollows and entrances made by various woodpeckers (family Picidae).

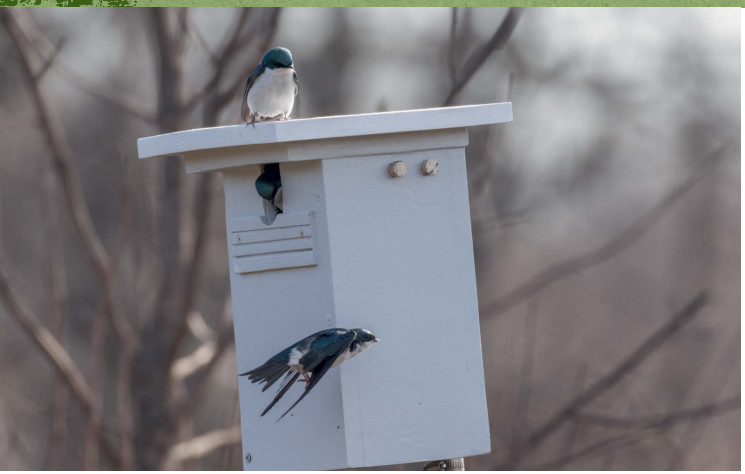
Birdhouses or nest boxes of all sorts can be purchased; however, many of these designs can also support invasive bird species. The National Audubon Society has published *The Birdhouse Book*, which illustrates how to build twenty species-specific nest boxes, and other organizations have also published designs that are available online. Invasive species, like European Starlings (*Sturnus vulgaris*), House Sparrows (*Passer domesticus*), and various doves (family Columbidae), utilize structures intended for native birds, sometimes forcibly removing native species. Luckily, there are methods to increase the likelihood of getting native species to use nest boxes. One of the most important aspects of placing a bird shelter is to ensure that the placement fits typical habitat requirements, including height, shade, and nearby vegetation cover. European Starlings and House Sparrows are more likely to nest in boxes (or cavities) that are near buildings. Native birds are more likely to use boxes that are placed away

from buildings, with specific features nearby. Bluebirds (genus *Sialia*), for example, prefer more open areas where they can hunt, but they also like intermittent perches between 3 feet (1 m) and 5 feet (1.5 m) off the ground, cleared or low-growing herbaceous plant communities, and available water. Purple Martins (*Progne subis*) also do well in these same settings but prefer communal shelters placed higher. For non-cavity-nesting birds, there are small nest platforms that target Northern Mockingbirds, American Robins (*Turdus migratorius*), cardinals (genus *Cardinalis*), and doves. These platforms are easy to make at home; just make sure to include a small lip on the platform to help secure nests and for fledglings to perch on. See the chapter 2 section "Wood" for design instructions to convert logs into a birdhouse.

An additional shelter type provides short-term refuge from hail and downpours. During extreme weather events, birds often seek shelter on porches, under cars, and in nest boxes. Installing a simple, wide, roofed area that birds can take temporary shelter in and providing suitable perches in other already protected spaces will support birds in inclement weather. Overall, structures can be as simple as a perch twice the bird's height under roof overhangs and on porches, to more complex, stand-alone features erected on poles and fences or placed in trees. Designs should include sturdy roofs that are wide enough to protect a few songbirds at a time. These structures should be placed in open spaces (including areas within trees) for birds to easily fly into and perch.

No matter which bird species you are trying to provide shelter for, it is imperative that the shelter not get too hot or fill with water. Midday sun can heat up shelters

Purple Martins (*Progne subis*) have specific nesting requirements that are accounted for in structures for purchase. In nature, their nests occur in hollow limbs of tall trees and cacti.



Tree Swallows (*Tachycineta bicolor*) using a nest box that is well placed and has a structure designed to prevent overheating.

well beyond 120°F (50°C), which kills broods. Even in the wild, animals build their nests in unsuitable areas, which ends up killing their young, so it is easy to attract birds to their own demise. Proper placement, air flow, and shade help prevent shelters from overheating. Boxes and shelters for species that prefer to nest in hollows in full sun should utilize designs approved for wildlife and thick materials, have good air flow, and may even warrant a secondary shading structure. Bluebird boxes, for example, can be placed on the north side of a post, are built with thick cuts of wood that keep high temps at bay, and have gaps in the floor and roof to help prevent the boxes from overheating. Small, roofed platform structures that are used by cardinals and doves can be hung on the north or east side of bushes and trees with open canopies, or inside the open space below large, closed-canopy trees. Make sure all nest structures are secure, as very few bird species will nest in swinging or rattling houses.

An Eastern Bluebird (*Sialia sialis*) nesting box on a post in a landscaped area can be used by a variety of native wildlife. This specific house has an extra layer of wood around the entrance to prevent birds and mammals from widening the entrance.

It is also important to keep birdhouses spaced out (except for Purple Martins and other social nesters), as most species are territorial. Urban yards usually provide nesting space for one or two species at a time. Make sure to keep the shelters more than 40 feet (12 m) apart, and try to provide shelter for different species. Keep in mind that some bird species only nest in the structures they build, but they need specific vegetation structure. For example, orioles (genus *Icterus*), blackbirds (family Icteridae), Verdins (*Auriparus flaviceps*), and Cactus Wrens weave intricate nests. To encourage these birds to nest in an area, provide plants and the vegetation structure they prefer to nest in. Cactus Wrens and Verdins prefer shrubs with spiny branches that grow at least 4 feet (1.2 m) tall: tree chollas (genus *Cylindropuntia*), Allthorn (*Koblerinia spinosa*), sweet acacias (genus *Vachellia*), and barberries (genus *Berberis*). Taller trees with thin branches, including oaks (genus *Quercus*) and willows (genus *Salix*), can attract blackbirds and orioles. Providing tall grass nearby that birds can use to build their nests will also encourage these species to occupy gardens.

— Bird Feeders

Many gardeners really enjoy using bird feeders to attract birds to their garden. Even though many birds enjoy bird feeders, feeders can negatively impact the area and bird populations by spreading disease or supporting invasive bird species. If you decide to put a bird feeder in your garden (for seed eaters or hummingbirds), make sure to check local wildlife extension and group bulletins monthly. Each group should provide alerts of disease outbreaks that can be spread at feeders as well as migration updates.

A Chipping Sparrow (*Spizella passerina*) sits at a seed feeder for perching birds. Feeder shape, size, and placement affect which birds are willing to visit.

Throughout the year, different birds migrate through your area. You can update seed selections in your feeder to cater to migrating species. This will help attract a wide variety of birds to your garden throughout the year. Selecting seed for native birds is also important because typical birdseed mostly attracts invasive bird species. No matter if you change seed selections or keep the same seed type in the feeder from week to week, it is important to clean the feeder once a week to every two weeks. Simply soak the feeder in a 20% bleach solution, scrub, rinse, and dry. This prevents the spread of diseases like avian conjunctivitis and salmonella. If an outbreak occurs in your area, take down the feeders until the outbreak is under control. Local extension offices should have updates and information about local diseases and concerns.

It is vital to hang feeders less than 3 feet (1 m) or more than 30 feet (10 m) away from picture windows, to reduce window-strike injuries and deaths. "Clear" mesh screens can be placed in front of windows to soften impacts. There are also UV patterns that can be applied every six months and window decals that help prevent window collisions. Feeders should be hung in open areas to prevent cats and other predators from hunting birds at the feeder.

Other wildlife are attracted to bird feeders, including predators of birds, squirrels, mice, and even bears. Various deterrents can be used for squirrels, including spicy pepper seeds, mechanical barriers, and cages, but nothing is 100% effective. Birds also drop seed to the ground, making it available to non-climbing wildlife. Cleaning under the feeder is important to prevent diseases from spreading to wildlife feeding

Window strikes, especially against picture windows and those on tall commercial buildings, are estimated to kill over one billion birds a year. Technological advancements have found near-invisible UV reflecting materials and mesh nets that can significantly reduce collision risk. Affordable cling films and solar screens that reduce window strikes are available for homes.

on fallen seed. Washing the area with water, removing old seed, and letting the area dry every month will help.

Hummingbird feeders are beneficial for local populations, especially in years when birds arrive before plants are in bloom. Cleaning feeders twice a week to daily in hot weather is necessary, as the sugar water spoils quickly. Clean with 20% bleach, just like for seed feeders. Hang feeders in protected areas, away from direct sunlight, to prevent daily temperature swings from emptying liquids and attracting stinging insects. In many areas, daily temperatures can span 20 to 30 degrees Fahrenheit, and saucer feeders are a better option over gravity-fed bottle setups. Small insects are also part of the hummingbird diet, so avoid using insecticides around these feeders to prevent accidentally poisoning birds.

Suet, a beef-fat product, is easily digested and metabolized by many birds, including chickadees (genus *Poecile*), jays (family Corvidae), nuthatches (genus *Sitta*), and flickers and other woodpeckers (family Picidae). In the wild, these birds look for dried animal fat on fresh and old carcasses. It is best to buy suet because commercial preparations prevent melting and are less likely to become rancid; however, suet can be made at home. Peanut butter is an acceptable substitute. Options for purchased

A group of hummingbirds (family Trochilidae) mob a feeder. Some species share feeders, while others are very territorial.

A Downy Woodpecker (*Dryobates pubescens*) at a feeding station with a suet-feeder cage. During winter, suet is important for many birds that would naturally feed on fats from wolf kills and insects. You should use only correctly prepared suet; animal fats from cooking are not acceptable without proper preparation.

suet cakes and suet blocks include solid blocks and mixed blocks. Typical additions to blocks include birdseed, sunflower seeds, fruits, nuts, and even dried insects.

Placement of suet and suet feeders should follow the same guidelines as bird feeders to reduce the risk of harm to birds. It is also important to put suet out only during cold winter months. Heat melts less-rendered fats and causes the suet to become rancid very quickly. Some store-bought blocks say they are safe up to 100°F (37.7°C), which means they will not melt on warm winter days; it does not mean they should be out during summer. Suet feeders also attract other wildlife, including bears, squirrels, and raccoons, so be mindful of how those animals affect the area and the structures the feeders are on.

— Tips for Keeping Birds Safe

- Birds are exposed to many dangers in urban areas. Although some predators, like Cooper's Hawks (*Astur cooperii*) and black rat snakes (genus *Pantherophis*), are less common in neighborhoods compared to wild areas, other risks are present. These risks include cats, mesopredators like Common Raccoons (*Procyon lotor*), squirrels (yes, squirrels; family Sciuridae), and skunks (family Mephitidae), window collisions, vehicle strikes, entanglement in fabrics, and poisoning. Even if you are not encouraging birds with feeders and baths, try to minimize these threats.
- Squirrels are nest predators that regularly consume bird eggs and chicks. Placing squirrel guards on nest-box posts and other general squirrel deterrents can reduce bird-nest predation.

- Regarding cats, the most effective thing to do is to keep them indoors. Loud collars generally do not help, due to the way cats stalk. House cats are responsible for killing billions of birds and other wildlife each year.
- If you have large picture windows, place deterrents to prevent window strikes and follow the tips listed earlier for hanging feeders.
- When birds build nests in your yard, avoid walking up to the nests, as this can help skunks and raccoons find their way there as well. Also monitor squirrel activity and try to keep the squirrels away.
- Lastly, avoid using pesticides. Since most songbirds feed insects to their young, insects killed by insecticides will be foraged on and fed to nestlings. Similarly, pesticides can make it into puddles and other areas where water accumulates after rains.

It is impossible to make your garden perfectly safe, but by being mindful and removing as many risks as possible, you will ensure your yard benefits the local bird population.

A Scarlet Tanager (*Piranga olivacea*) at a garden birdbath. Ensuring predators cannot easily stalk birdbaths is important for bird safety.

MIGRATING BIRDS AND SUBURBAN AREAS

Most songbirds in North America undertake seasonal migrations, which are affected by urban areas. Birds make migratory flights at night, reserving resting and feeding for the daylight hours. Studies have shown that migratory birds are attracted to city lights and can become disoriented in brightly illuminated areas, and due to increased resources in developed areas, some birds overwinter there instead of migrating. Well-planned urban development can create beneficial habitat for many migrating species and, with gardens, are an important piece of habitat networks.

Wilson's Warblers (*Cardellina pusilla*) are common migrants throughout the United States; however, they are not often seen in yards. They prefer wet areas and energetically dart around thickets, hunting for insects. Landscaping with native plants and promoting insect populations helps these birds along their migration.

Providing food for migrating birds is incredibly important because so much stopover habitat with suitable forage has been lost. In addition to the overall habitat loss in developed areas, invasive species also affect natural areas, which decreases available forage. Keeping summer feeding stations filled during migration and winter is important. Areas that do not have bird feeders out in summer benefit from the placement of feeders in fall and spring to help fuel bird migrations. Landscaping with a mix of native shrubs, vines, and trees that produce berries in fall and winter provides food for a larger number of species than bird feeders and can be paired with seed feeders and watering stations. Areas with mature trees throughout the neighborhood support the most bird species, but grassland and shrubland specialists seek out tall herbaceous gardens and shrubs. Providing feeders at lower heights—for example, near the top of vegetation in meadow areas—will make grassland birds feel safer; however, neighborhood cats must be kept from the area to prevent mortality. Check local extension offices for key resources that may benefit birds flying through your area.

Ruby-crowned Kinglets (*Corthylio calendula*) are regularly seen on the ground, darting through bushes, and heard high up in trees. They migrate and spend winters in the southern United States and Mexico and breed in the northern United States and Canada. They visit some seed feeders but prefer foraging elsewhere.

A perched American Robin (*Turdus migratorius*).

— AMERICAN ROBIN

American Robins (*Turdus migratorius*) are an abundant and common species that has adapted well to urban habitats. It is one of only two species that was documented to be unfazed by the density of human structures in a long-term study done in the 1970s. The Gray Catbird (*Dumetella carolinensis*) is the other species. Their success in urban environments is partly due to their tendency to hunt insects and arthropods in open areas. Naturally occurring cleared areas can be found along lakes, shortgrass meadows, and clearings caused by mammals like prairie dogs. In urban and suburban environments, mowing and pavement keep areas open. These areas have the preferred structures for American Robins to hunt in the overall noise, and the robins also tolerate the disturbances, pollution, and hazards that accompany suburban habitats.

Similarly, American Robins are able to adapt to nesting in urban and suburban areas. A study done in Quebec, Canada, found that over 70% of nests were built in coniferous, evergreen trees. Other nest sites included deciduous trees, mostly maples (genus *Acer*), and fewer than 3% were built on human structures. A few studies have also measured the height at which nests are built. Most data found nests in suburban areas to be located between 13 and 17 feet (4–5 m) off the ground; however, it is not uncommon for robin nests to be located less than 5 feet (1.5 m) off the ground.

An American Robin (*Turdus migratorius*) and a nest full of soon-to-be fledglings on a porch. Nesting preferences differ by individual.

Creating attractive habitats for American Robins simply requires keeping important resources in the garden. Shallow water features attract robins for drinking and bathing. Open areas, like mowed paths, lawns, and other cleared spaces that mimic herbivore cleared vegetation, attract adult birds for foraging. Creating habitat for their prey, especially beetle grubs, earthworms, spiders, and other invertebrates, as well as planting species that produce berries and fleshy fruits will keep them coming back. Tall, dense evergreens, like spruces (genus *Picea*) and deciduous maples (genus *Acer*), American Sweetgums (*Liquidambar styraciflua*), and even tall fruit trees, also have the potential for nest sites. Reducing and eliminating chemical applications, especially pesticides, will increase the abundance of insects that they feed themselves and their young. Migratory American Robins also benefit from landscapes filled with native plants that host insects and produce berries in winter.

— BLUE JAY

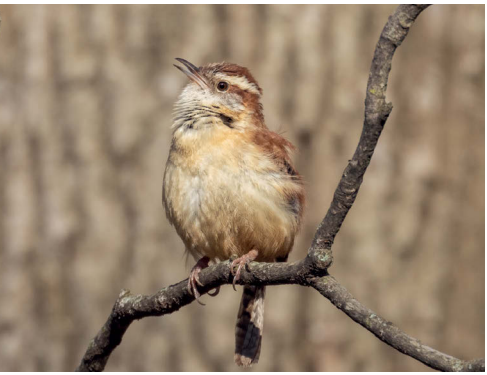
Blue Jays (*Cyanocitta cristata*) are common throughout many regions of North America, in forested areas east of the Rocky Mountains. These birds prefer areas with dense shrubs to tall trees and do well in urban areas. Their diet consists of both seeds and insects, and they are common at feeders. Nesting occurs on large branches in big canopies where they lay between two and seven eggs; they produce one brood a year. Parent Blue Jays both forage to provide for the young.

Two Blue Jays (*Cyanocitta cristata*) bathe in a ground-level, disappearing water feature complete with pump.

Your chances of attracting Blue Jays drastically improve if you plant oaks (genus *Quercus*), beeches (genus *Fagus*), cherries (genus *Prunus*), and other large, seed-producing trees, as well as having mature tree canopies nearby. Adding water features, promoting insects, and adding large-seed bird mixes to feeders will also improve the likelihood of Blue Jays visiting your garden.

— CAROLINA WREN

Carolina Wrens (*Thryothorus ludovicianus*) are frequently encountered in neighborhoods within their range that also host lots of trees, as they prefer open woodlands. These birds are very active; they can raise two or three broods a year and are an absolute delight to have around. Unlike many other birds in North America, mating pairs establish permanent territories that they defend all year. Females and males work together to hunt, build their nest, and keep would-be predators away.



A Carolina Wren (*Thryothorus ludovicianus*) serenades from its perch.

Encouraging Carolina Wrens to visit a garden requires robust insect populations, as well as summer and winter fruits, berries, and seeds. Carolina Wrens are small yet efficient predators that consume small animals, including an assortment of insects like caterpillars, grubs, grasshoppers, moths, true bugs, and crickets, as well as spiders, snails, small lizards, and tree frogs.

Nesting sites are usually located between 3 feet (1 m) and 10 feet (3 m) off the ground in a cavity or crevice. In urban areas, nest sites have been reported in hollow branches, roof eaves, open vents, upturned root crowns, unused barbeque pits, nest boxes, and brush piles. Artificial nest boxes designed for Carolina Wrens are roughly 5 inches (12.5 cm) tall and 4 inches (10 cm) wide, and, instead of a round entrance, have a 1-inch (2.5-cm) gap on one side, between the wall and roof, for birds to enter . Adding a water feature to the area will also help hydrate birds and may provide secondary hunting grounds.

A Mourning Dove (*Zenaida macroura*) nesting on a thick branch in a Honey Mesquite (*Neltuma glandulosa*) shrub in an undeveloped setting. Nests can be very haphazard or well built, depending on the individual.

— MOURNING DOVE

One of the more abundant native species of birds in urban habitats is the Mourning Dove (*Zenaida macroura*). These birds are frequently seen in pairs on power lines or perched on the ground. They are similar in appearance to the locally common, native White-winged Dove (*Z. asiatica*) and the introduced Eurasian Collared Dove (*Streptopelia decaocto*). All three species have diets that are almost exclusively seeds for both adults and young.

Attracting Mourning Doves to a garden is as easy as providing a cleared area on the ground with birdseed. However, creating more natural habitats requires a bit more planning. In non-urban landscapes, Mourning Doves search for seeds on the ground. Garden designs that include bare ground or rocks between bunchgrasses, shrubs, and small trees mimic their natural habitat. Nest sites include tree canopies, shrubs, shaded ledges, nesting platforms, and the ground.

A Mourning Dove (*Zenaida macroura*) nests on a plant stand among pots in a garden. Nests are regularly reported from areas near high foot traffic, including the ground, door wreaths, and patio railings.

Food plants include large-seeded grasses like bristlegrasses (genus *Setaria*); cultivated grains like millet, wheat, and sorghum; ragweed (genus *Ambrosia*); and wild sunflowers (genus *Helianthus*). Mourning Doves also need small gravel bits that they consume to help with digesting seeds; these bits are usually already present in urban situations but can be supplemented with crushed oyster shell.

— NORTHERN MOCKINGBIRD

Common residents of urban and suburban landscapes, Northern Mockingbirds (*Mimus polyglottos*) are often seen perched on lampposts or tall shrubs, or running across the ground hunting insects. They rarely visit bird feeders, but gladly bathe in birdbaths. Their diet consists of insects and berries. Males and females of this species work to provide for their young and defend their territories, which can be a nuisance when they construct their nests near sidewalks or doors.

A Northern Mockingbird (*Mimus polyglottos*) perched in a tree.

To encourage these birds to visit, maintain mowed areas with no pesticides, where they will hunt for insects. Their nests tend to be located in woody plants with dense twig growth that supports the cup-shaped structure. Planting fruiting trees and bushes like mulberries (genus *Morus*), hawthorns (family Rosaceae), blueberries (genus *Vaccinium*), and raspberries (genus *Rubus*) also attracts adults to visit areas.

A pair of Red Foxes (*Vulpes vulpes*) standing outside their den. For some gardeners, foxes are welcome guests in yards, while other homeowners do not want them around. Their presence is important in the ecosystem.

All wildlife depend on specific resources for their life cycle. Small-scale conservation projects can provide resources for certain stages of an animal's life cycle (especially for more transient and mobile species) or support every part. Each of the profiles in this section aimed to include details on necessary resources and microhabitats for reproduction, what the animals forage on, and how and where organisms make it through winter. Take this same approach with any target wildlife you want to support with your landscape. Keep in mind that native plants are just as important as providing suitable shelter, especially for most insect species. When data are sparse, try to replicate the sheltering habitats species use in non-developed areas and evaluate the local characteristics that might allow them to survive winter and summer temperatures. Also consider the absent megafauna and if they would be facilitating the formation of areas the species would use. The more microhabitats that can be included in designs, the higher likelihood wildlife will find the area suitable.

A Coyote (*Canis latrans*) sits on a prairie dog (genus *Cynomys*) town, a natural area that once existed throughout much of the central United States but is now reserved to just a few locations. Re-creating resources and the effects of animals on habitats is important for suburban and urban areas.

NUANCES AND PITFALLS

Sections in this chapter cover many of the nuances that exist within conservation and address a variety of ideas that are often misrepresented. Wildlife gardening and ecology are fairly new, so it is understandable that ideas and messaging can lead to confusion and misapplication. By parsing out details and explaining goals and reasons, land managers and gardeners can identify better practices and help teach community members.

Chelsea Chop, Deadheading, and Other Pruning Methods

Since 1912, every May, the Chelsea Flower Show takes place in London. As gardeners and horticulturists prepare for this show, many herbaceous plants are pruned, and flower stalks are chopped down to control the bloom times of plants, prevent stems from toppling or falling, and provide peak blooms for the show. Plants respond to trimming in many of the same ways they respond to being browsed naturally, and new growth begins from secondary buds. Specifically for the Chelsea Flower Show, plants are trimmed back by one-third of their mass, to shape them and promote new blooms. Over time, late-April, early-May pruning became known as the Chelsea Chop. Gardeners in North America have also adopted this pruning schedule, which in some regions can be appropriate. However, just like No Mow May (discussion of this below), the timing will be off for many regions outside the area where it was first developed.

In London, the frost-free growing season starts in late March. This means that plants typically have six weeks of spring growth at the time gardeners implement the Chelsea Chop. Another key point to recognize is that the plants that typically undergo this pruning method are not native species, but cultivars, hybrids, and plants that are not native to London. Therefore, the Chelsea Chop should be modified for use in native plant gardens of North America.

Hydrangeas (genus *Hydrangea*) are one of the many plants grown for their gorgeous blooms in late summer. However, these plants do not support many wildlife. Choosing native plants with large blooms is always best for wildlife.

The best way to utilize the Chelsea Chop in North America is to implement the pruning method six to seven weeks after the last frost date. Make sure to only prune perennial herbaceous plants that tolerate heavy browsing. For example, common milkweed, most irises, and many lilies do not respond well to early trimming or heavy pruning, but common yarrow, salvias, and upright prairie coneflowers do. Similarly, plants that often become leggy are good candidates for this pruning method and trimming in general.

Deadheading is a practice in which flower heads are removed after their petals fall and before they turn to seed. This action helps the plant divert energy into producing more flowers instead of growing fruit, but it only works on plants that produce multiple blooms a year. It does not work on many species, including most lilies, fruit trees, berry bushes, and cacti. In gardens supporting wildlife, removing seeds removes forage for potential target wildlife. However, encouraging more flowers can help feed native bees and other pollinators. For example, deadheading purple coneflowers (genus *Echinacea*) removes seed heads that would feed goldfinches and other birds, but increases new blooms used by pollinators. One way to provide both seeds and continuous flowers is to only deadhead specific plants, while allowing others to go to seed. By deadheading plants near borders or closest to areas where people will most often view the garden, you can foster a constant burst of color. Plants farther back can be left to go to seed and continue their annual cycles undisturbed, providing forage for seed eaters.

Woody plants, especially trees, are often trimmed in one of two ways: topping and thinning. Topping a woody plant removes most of the branches and retains just a few major ones, which are also cut to create bushy growth at the ends. For mature trees, such a pruning technique can lead to infections and a weaker secondary growth, which means branches can snap off more readily. Thinning selectively removes shoots and trims branches early in their development just above buds that can continue to grow.

A herbaceous garden full of plants that benefit from light pruning during the growing season and from early-spring removal of dead vegetation.

A herd of Moose (*Alces alces*) browsing in winter. Large animals feeding and their overall movement in landscapes help clear withered and dead vegetation, providing better growing conditions for plants in spring.

MUSHROOM TREE

Topping mature trees is most often discouraged as it leads to weak growth, increased susceptibility to diseases, and often a slow death. However, topping certain tree species, when they are sick or broken, to a low height can create unique looks, while providing important shelter and forage for animals. In conservation, when land managers remove trees for shrubland restoration, some top a few trees between 1 and 6 feet (0.3–2 m) off the ground. This allows the tree to grow new shoots that form a dense canopy at shrub height that some shrubland birds use for nesting. It also provides key resources while newly planted shrubs establish.

In urban areas, if a tree is sick or snaps during a storm, topping the tree at a low height sometimes leads to the tree resprouting. Resprouts provide forage for insects and shelter for birds if maintained correctly. Trees stumps cut close to the ground can also resprout, but these often encourage sprouts to show up along the roots far from the main trunk. Most landscapers and gardeners try to kill stumps completely, but these new shoots can be trimmed into shrubs and quickly incorporated into a landscape as a bush. It is not a good idea to let the regrowth become a tree again because the new branches are more easily broken. However, a young replacement tree can be planted nearby and allowed to mature while the topped tree still continues many of its roles in the ecosystem. New growth on the topped tree should be trimmed to keep it short and shapely and prevent the weak growth from becoming an overhead falling hazard.

Tree species that often regrow from stumps include oaks (genus *Quercus*), maples (genus *Acer*), birch trees (genus *Betula*), mulberries (genus *Morus*), sweetgums (genus *Liquidambar*), and willows (genus *Salix*). These species also support an incredible diversity of insects, birds, and wildlife. In small yards where a mature oak tree is not feasible, intentionally topping the younger tree to keep it at shrub height is a fantastic option.

In natural settings, plants experience damage regularly from weather, herbivores, and infections. Many plants that are common forage for larger mammals or that host numerous herbivorous insects seem to tolerate pruning the most. This is likely due to the constant removal of tissue that occurs naturally and is mimicked by pruning. Without large animals feeding on foliage and shoots, many herbaceous plants continue to grow and topple in gardens. However, once trimmed, the plants have better structure to stay upright. Large animals are also responsible for browse lines and removing limbs that plants stop supporting as their taller branches create too much shade. Trimming back these lower branches helps clear out areas where birds and insects fly and where shade-tolerant plants grow, and provides a more manicured look to gardens. In other words, pruning plants is important for their health and mimics some of the actions of extirpated megafauna; it should be a common practice in wildlife gardens. Additionally, herbaceous plants and shrubs that are regularly foraged on should be trimmed lightly and often throughout the growing season instead of once or twice a year.

Climate Change

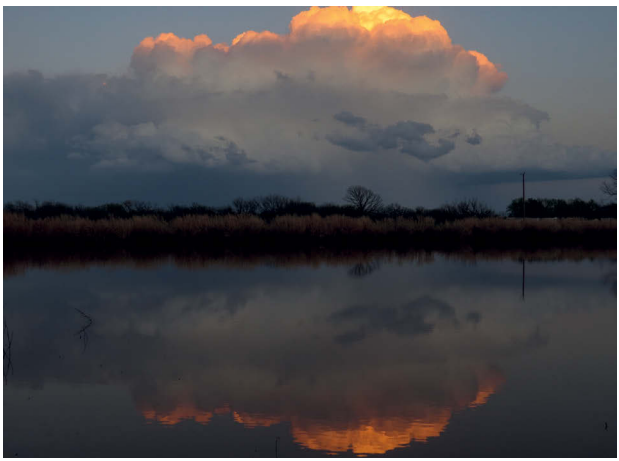
One of the greatest problems the world is experiencing right now is human-caused climate change. Incredibly, politicians, big polluters, and media personalities have turned a scientifically understood problem into a debate, which has only prevented the implementation of mitigation measures. Put simply, in the past 200 years, humans have increased the carbon dioxide in our atmosphere by nearly 30% and have also increased the amount of methane, which is a worse greenhouse gas. Both of these chemicals absorb heat from the sun, warming the planet, especially the poles. The North and South Pole strongly influence our weather patterns, as well as ocean currents. When the poles heat up, weather phenomena interrupt and intensify, which

Lightning streaks across the sky in a late-night thunderstorm. Thunderstorms are increasing in intensity as the atmosphere gains greenhouse gases.

leads to prolonged droughts, stronger storms, heat waves, deluges of rain, and even localized record winter lows. Whether or not a person understands that climate change is happening, the effects will continue to impact our local weather, ecosystems, and gardens.

One of the benefits of using native plants in garden designs is that they are supposed to do well without supplemental watering after they have established. However, climate change is shrinking the ranges of many plants and animals. Earth has already increased a full Celsius degree (just shy of 2 degrees Fahrenheit) and is on track to experience an additional average increase of 2 degrees Celsius (5 degrees Fahrenheit) by the end of the century. Unfortunately, this does not mean a simple increase in temperature; it means increased volatility in our atmosphere, which affects rain patterns, precipitation totals, snowfall, seasonal low and high temperatures, nightly low temperatures, and even wind speeds.

Snow is an important feature in many landscapes. Soils beneath snowpacks are insulated from extreme cold temperatures and sporadic hot winter days. Melting snow slowly hydrates soils that plants depend on in spring.



Thunderclouds on the horizon with precipitation. Annual patterns of rain are already noticeably different compared to 70 years ago.

As climate change affects rain patterns, supplemental watering will be necessary, as well as dealing with too much rain. Precipitation patterns will change differently for each ecoregion, but some commonalities will exist throughout. For some areas, the overall annual amount of rain will not change much, but the timing of rainfall events will. In most ecoregions, rain will be less frequent, which means short periods of drought. When rain occurs, more rain will fall, leading to increased runoff, flooding, erosion, and soil saturation. In other words, some areas will experience longer dry periods, followed by overwatering, possibly at rates that will be too fast for soils to absorb. Across the globe in 2022 and 2023, isolated regions experienced more rain in a day than historically recorded in the entire month. In regions like the Southwest, more severe droughts are expected that will last years longer than normal. Areas in the Northeast are expected to receive more rain, with many flooding events and heavy snowfall, while the South may experience never-before-seen droughts.

Wildlife habitat designs will require extra planning to handle these weather events. Most planting areas should be able to receive supplemental watering during drought periods. Beds should also have a slight grade to allow drainage when severe rain events occur, but not so much that erosion is a problem. Full vegetation cover is the best way to prevent erosion; however, in areas where bare ground or mulch cover is exposed, installing water bars and barriers helps keep soils in place. Rain gardens or gardens with rain barrels should also be set up to handle more water during each rain event. Areas where water will flow in rain events should have reinforcements to slow water flow and prevent scouring and erosion. Mimicking beaver dams along small creeks and thus creating pools and runs also creates more microhabitats.

For North America, when temperatures rise at the North Pole, arctic air is pushed farther south. Winter storms created in these arctic airs will continue to set new winter lows. However, overall, the average winter temperatures will be higher than

A patio garden with a well-designed pond that includes a spillway for when rain events are too much.

normal. This means that plants and animals living on the coldest extremes of their range will likely perish in these storms. For example, in February 2021, swaths of the continental United States experienced a polar vortex that killed people, wildlife, and plants. In Texas, the extreme cold lasted for nine nights. Areas around Houston and the Gulf of Mexico experienced mass die-offs, including native and non-native large trees, shrubs, and ocean life that could not tolerate prolonged freezing temperatures. In western Texas, mature cacti and flowering plants at the northern extent of their range had mass mortality as well.

As these extreme cold events become more frequent and set new lows, gardeners will lose plants. Over time, the USDA Plant Hardiness Zone Maps will change, but be aware that the USDA uses averages and not prolonged extremes, so the current updated maps are misleading. Land managers and gardeners will have to adapt by using species that can tolerate prolonged temperatures below the historical lows of their area. At the same time, summer highs and droughts will also affect which plants can survive summers. Since the year 2000, daily high temperature records have been shattered, as well as records for the number of days when extreme high temperatures are present back to back. Less talked about is the fact that nightly lows have stayed well above their average temperatures, which allows soils to heat up and prevents cooler microclimates from forming. In smaller gardens, shade cloths may be feasible to help assuage the heat, but in larger acreages, simply selecting species that can endure the new stressors is recommended.

Planning for climate change is difficult and daunting. Identifying ways to control abiotic factors will help with habitat management. Similarly, creating habitat for species that are not at the edge of their range can prevent die-offs from weather extremes. Also, keep in mind that the world has pulled together in recent decades and listened to scientists when it comes to global problems. Prime examples include addressing the hole in the ozone layer and banning the use of Freon, as well as

A week after winter storm Uri let up, beaches along the gulf continued to collect mortalities. Extreme weather events like this one, which occurred in February 2021, are locally devastating and are expected to occur with more frequency. Populations will have difficulty recovering if these events happen more often.

A mature Bald Eagle (*Haliaeetus leucocephalus*) soars through a clearing in a forest. DDT nearly brought this species and other raptors to extinction, but global efforts banning the use of DDT have allowed populations to rebound.

addressing raptor declines caused by the use of DDT. So, it is possible that the world will work together again and climate solutions will be implemented.

Leave the Leaves

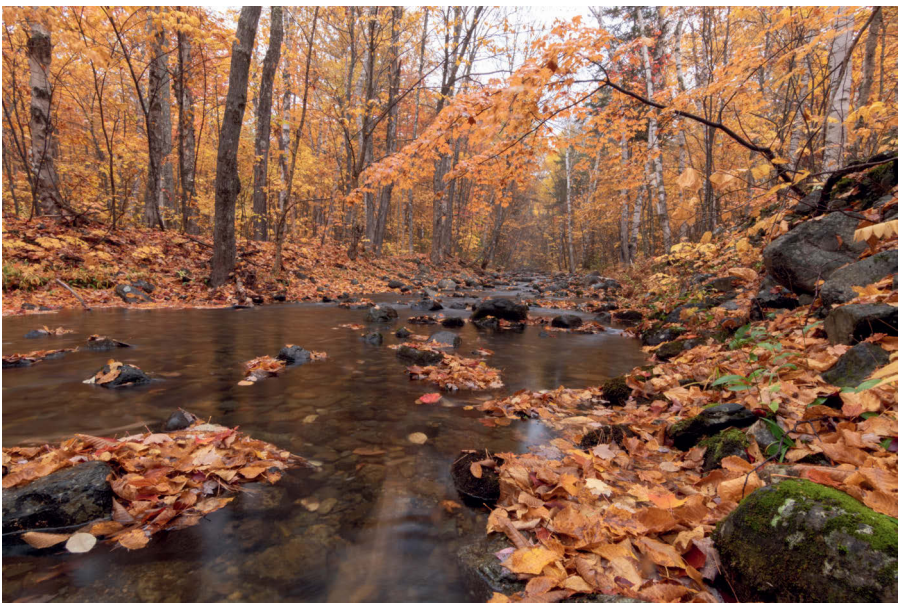
In urban and suburban areas around the globe, a cacophony of leaf blowers, rakes, and crinkling trash bags punctuates fall days. Many supporters of the Leave the Leaves program point to this noise pollution as one of the many reasons to curtail yard cleanup. Leave the Leaves is a program that was designed to help overwintering animals, especially insects, and to fight the status-quo messaging on manicured lawns. But the Leave the Leaves messaging is a bit oversimplified, probably because "If it falls in your yard, keep it in your yard, but feel free to tidy up and please don't mulch" is a bit cumbersome. Overall, the most important message is to keep the leaves as intact as possible and on (or at least near) your property. When you keep leaves around, insects that use leaf litter stay on the property. Having leaves intact and on your property also helps wildlife that overwinter or pupate in leaf piles. When yard waste

A gorgeous landscape with fall leaves across a mowed lawn. Full-sun plants typically found away from forests can tolerate some leaf cover, but dense leaf cover should be removed and piled in more suitable locations.

is mulched or bagged and sent off, insects in the leaves do not survive, and nest-creating animals have a harder time finding nesting materials. But leaves do need to be cleaned up from walkways, roads, and our full-sun, herbaceous plants. Leaving leaves that fall on full-sun, herbaceous plants can kill the plants. This is because they would not naturally be growing next to a mature deciduous tree due to habitat succession and are not adapted to growing through thick leaf drop.

When cleaning up, it is best to use a rake. Leaf blowers are a far second place when raking is not an option, but only if used gently and on dry, recent leaf fall. Rakes are better for wetter or older leaves. Leaf blowers that are set on high or that blast hot air are not good because these gusts and temperatures can harm animals present in the leaf litter. Although Leave the Leaves is a simple statement, it comes with a few nuances. Quite often, folks confuse animals using leaf piles to overwinter with a mostly incorrect notion that animals hunker down in the canopy of trees and then fall to the ground to spend the winter wherever those leaves land. A lot of people also misinterpret the slogan to mean they should not clean up the leaves at all. To be clear, it is absolutely acceptable to gently sweep or rake up leaves, but they should be piled on your property in an area that won't flood. If animals had a canopy-to-ground life strategy,

Fallen leaves around a stream in the Northeast. Insects would have perished if they were in leaves that fell into the creek. In both terrestrial and aquatic environments, most arthropods that depend on leaf litter choose areas once leaves have fallen and built up.



Leaf litter in a deciduous forest in Maine. The leaf layer in this ecosystem naturally accumulates evenly and stays less than a few inches thick. Leaf mulch in a garden should match this thickness, especially when covering bulbs and withered plants.

they would be susceptible to being blown into waterways, ponds, and puddles, only to drown. What usually happens in nature is that wind blows leaves into areas (under downed branches and between plant stems, bunchgrasses, or bushes), then wildlife select those piles as places to overwinter. Some animals even gather leaves to build nests or line their burrows, which can be inside the pile of leaves, within a hollow log, in tree canopies, or underground.

Cleaning up leaves is also important because many garden designs place plants from different habitats near one another. Open-grassland plants can tolerate some leaf litter but will struggle to grow through a dense matting. Spring ephemerals native to forests are on the other side of the spectrum and do well under leaf piles. In general, making sure leaf layers are not too thick in early spring is important as plants may not be able to grow through the materials. Loosening this layer also mimics the actions of absent rodents, large mammals, and even some bird species. It is always a good idea to loosen leaves directly above underground stems or to clear them away in early spring to help herbaceous plants and new seeds safely grow.

Monitoring, Responding, or Letting Nature Take Its Course

Too often, folks will observe a problem in their garden and be told to "just let nature take its course." While one of the goals of creating wildlife habitat is to help nature, it is critical to understand that our developed environments are out of balance and often require intervention. In many cases, letting nature take its course is the best option. However, there are a number of situations that require action. The best way to know when intervention is needed is to monitor your garden, keep notes, and apply some critical thinking using your knowledge of ecology.

Aphids (superfamily Aphidoidea) cover a plant stem and are cared for by ants. These aphids are regularly consumed by syrphid fly (family Syrphidae) larvae, lady beetles (family Coccinellidae), and lacewings (suborder Hemerobiiformia), but are protected by ants that consume their sugary secretions.

A healthy habitat supports a food web, in which some of the organisms we are trying to support become food for another animal. For example, many plants are eaten by aphids. The aphids then attract various predatory insects, which keep the aphid population in balance, and the plant can survive. However, there are times when the aphids become too abundant and are able to damage the plant beyond the point of healthy recovery. Once the plant begins to look sickly, most wildlife gardeners intervene and remove some of the aphids, in one way or another, to help the plant. Sometimes simply spraying the plant down with strong jets of water is enough; at other times, gardeners should manually remove the aphids or apply natural oils. A common rationale folks use to justify removing aphids is that, if we help the plant live, then insects can feed on it in the future. Even if we cannot articulate the reasoning, we also know that mature plants do not typically succumb to aphid infestations in nature. So, if aphids are too abundant, there is something out of balance, and it is best to step in and remove some of the aphids, as predators would do naturally. Since our gardens are out of balance and drastically more isolated than natural habitats, problems like this occur fairly regularly and require intervention.

A more complex problem that commonly occurs in gardens is an abundance of ants and predatory wasps. Healthy habitats support a variety of these insects, but wild landscapes also support animals that feed on both ant colonies and the hives of predatory wasps. Animals that prey on ants and wasps include armadillos, bears, birds, lizards, and toads, along with a variety of other invertebrates, like velvet ants. Wild habitats also typically have fewer nesting resources for predatory wasps compared to prey habitat. In contrast, urban environments have an abundance of roof overhangs that are well suited to support various wasp's nests and smaller, isolated prey

Bald-faced Hornet (*Dolichovespula maculata*) nests can house a few hundred active adult hornets, which hunt arthropods that they feed to their young. Although they are native to North America, in suburban habitats they can quickly diminish caterpillar populations.

habitats. In a similar fashion, urban environments have modified soils and irrigation, which promote certain ant species over others, including aphid-farming species and invasive species. Although many people may want to "let nature take its course," the reality is that without monitoring and intervention, our gardens can easily become wasp and ant habitats with high mortality rates for the insects being feasted upon.

It is difficult to know when predatory wasp populations or ant populations are too much, but there are some guiding benchmarks. An urban house should not have more than two active colonies of flying predatory wasp nests each year. These wasps include umbrella paper wasps (genus *Polistes*), Bald-faced Hornets (*Dolichovespula maculata*), and yellow jackets (genus *Vespula*). Similarly, ant colonies that forage far from their nests, like harvester ants (genus *Pogonomyrmex*), fire ants (genus *Solenopsis*), and acrobat ants (genus *Crematogaster*), may require some control

An armadillo (order Cingulata) searching for insects to eat. Feeding armadillos regularly destroy nests of ants, wasps, and bumblebees, which keeps their populations down. However, as with many mesopredators, armadillo populations are low in urban areas.

if colonies become too numerous. Invasive ant colonies, like those of the Argentine Ant (*Linepithema humile*) and the Red Imported Fire Ant (*Solenopsis invicta*), should be removed immediately because they decimate many wildlife populations rapidly. Native ant species, if they are not harming humans, property, or pets, should be monitored. Most ant species have small home ranges with low numbers and are very beneficial. There are also native ant species that have large home ranges and diets that can include leaves, seeds, aphid secretions, and active farming of fungus or meat. Meat-foraging ants eat almost any animal provided and even kill animals that cannot escape. Typical prey for meat-eating ants includes baby birds, lizards, amphibians, insects, arthropods, and the young of those animals. If the abundance of ants starts killing plants or animals, culling the ant population or reducing nest abundance to just a few per 500 square feet (46 m^2) is needed. In healthy ecosystems, if ants become overabundant, their predators will have more food, leading to more predators and a cyclic, growth-and-contraction population cycle. Similarly, wildlife would have more space between shelters and nesting sites, which would make it harder for ants to access.

Monitoring of overall areas, like microhabitats, in our gardens should regularly occur, and they should be reset every few years. A microhabitat reset prevents an area from being used by target wildlife for a season. Naturally, this would occur sporadically for many different reasons, including fire, drought, and random chance. In large expanses of land, wildlife populations shift and move, leaving areas vacant long enough that diseases, predators, parasites, and parasitoids are forced to find new areas or die out. This process resets the habitats, which are then repopulated and used again, continuing the cycle. Conversely, gardens are very attractive and isolated, which prevents many wildlife populations from shifting around the landscape and allows natural enemy populations to persist.

A predatory wasp carries a paralyzed insect back to its nest.

ANTS

Ants are an important component of the ecosystem; however, our yards are incredibly out of sync with the natural world. Most importantly, the major predators of ants and ecological processes that limit their nesting are absent from most urban areas. Ant colonies are raided by a variety of animals, including armadillos and bears, Pileated Woodpeckers (*Dryocopus pileatus*), lizards, and frogs. Many animals that would wreak havoc on an ant colony are generally not welcome in residential neighborhoods or simply do not do well in urban and suburban environments. A wide range of ant species, both native and invasive, do well in developed areas because there is prime habitat with disturbed, irrigated soils that are easy to nest in, scraps of food, and, if the ants are lucky, native plant gardens with aphids, seeds, and other food resources.

A surface entrance to a nest of harvester ants (genus *Pogonomyrmex*), which clear areas around the entrance and feed mostly on seeds. In developed areas, they are generally extirpated because people view them as pests, and their sting is very unpleasant.

Diseases and parasites can build up in ponds and soils. Areas with dense host-plant populations can support predators and parasitoids that feed on all of the offspring from insects that travel long distances, including butterflies, moths, sawflies, and beetles. When areas attract a species but their offspring are not able to make it to reproductive age, the habitat is referred to as a *sink*. To prevent a garden from becoming a sink, cut back host plants for a season every five to eight years. This will reduce the number of larvae in the area and force predators and parasitoids to move or die out. Allow seasonal ponds to dry out yearly, but also clean perennial water habitats to prevent fungus and other diseases from establishing. Create new areas with mulch, logs, and damp soils for animals to shelter in. After a month or so, either clear out the old logs/mulch or let the area dry out for a few months. Clean out bird boxes; check

Even though ants are an important component in natural habitats, in developed environments they can quickly become too numerous. This leads to the overpredation of caterpillars; increased farming of aphids, which can kill plants, including mature trees; and destruction of other wildlife, from lizard eggs to baby birds. Monitor the ants in your gardens. When they seem excessive, take action to mimic the absent predators and rebalance the ecosystems in our yards. It is important to let some ant colonies exist in our yards, but no gardener should feel bad about removing overabundant native ants, any invasive ant species, or ant species that harm humans or pets. Non-chemical treatments include pouring boiling water into the colony opening, slowly. Adding Dawn dish soap can improve the effectiveness of this method. Specialized delivery traps for insecticides, like ant stakes, can be placed near colonies to reduce insecticide use and prevent mass application.

Ants also have mutualistic relationships, including many gossamer-winged butterflies (family Lycaenidae). Here a caterpillar is cared for because of the hormones it secretes, which trick ants into acting as though the caterpillar is an ant larva.

An Unexpected Cycnia (*Cycnia inopinatus*) is parasitized by a wasp in the genus *Therion*.

for parasites infesting the shelters and clean appropriately. Carry out similar actions for all areas that host wildlife and can become sink habitats. If you do this, overall populations will remain healthy, and the natural cycles that we are trying to support will be able to continue in a more balanced manner.

No Mow May

As winter wraps up and spring starts, posts flood social media promoting No Mow May to help pollinators and other wildlife. Soon to follow are people saying the program is terrible and bad for animals. As with most things in ecology, this issue is nebulous. It is important to understand that No Mow May started in England, where many lawn weeds of North America are native and where spring is in full swing in May. The program was developed to combat harmful standards for lawns that many people think are beautiful and need to be flower free. This needs to be repeated. No Mow May is a social movement to combat harmful lawn standards that remove flowers and plant diversity. Additionally, the program was intended to help provide forage for emerging pollinators and insects, but in England. The goal of promoting No Mow May is to engage people who are not already aware that lawns are bad for the environment and introduce them to wildlife needs. Once lawn lovers are engaged through No Mow May, the hope is that they will use fewer chemicals on their lawn, allow more flowers to grow in their mowed areas, and possibly even take actions to remove some of their lawns and create wildlife-friendly habitat. At the very least, it will help folks see plant diversity as a norm, rather than their ecologically barren, monoculture lawns.

In North America, the same problems exist around lawns. Even in places where folks are not treating their lawns with herbicides and pesticides, many landowners simply mow more area than is necessary. While mowing, they have the blade height

A riding mower clears a large area to maintain a manicured lawn.

Large expanses of monoculture lawn are the target audience for No Mow May. The eventual goal is to have fewer homes with full lawns and more yards with areas landscaped with native plants and habitat for wildlife.

A large acreage of mowed lawn, whose owners are the perfect target audience for No Mow May. Most of this lawn is mowed at the expense of the homeowners' time and money and at a terrible ecological cost. Reducing this lawn into islands of native plants would reduce time spent mowing and increase wildlife habitat.

set too low for most flowering plants and are often only mowing because that is what they were taught to do. No Mow May programs provide an opportunity to engage these landowners by introducing them to lawn alternatives. However, in England, most of the country experiences seasons at roughly the same time. In North America, spring weather starts in February in the southern latitudes, while areas in the north (and higher elevations) can experience late snowstorms in May. So, although No Mow May has the potential to engage landowners in North America with lawn

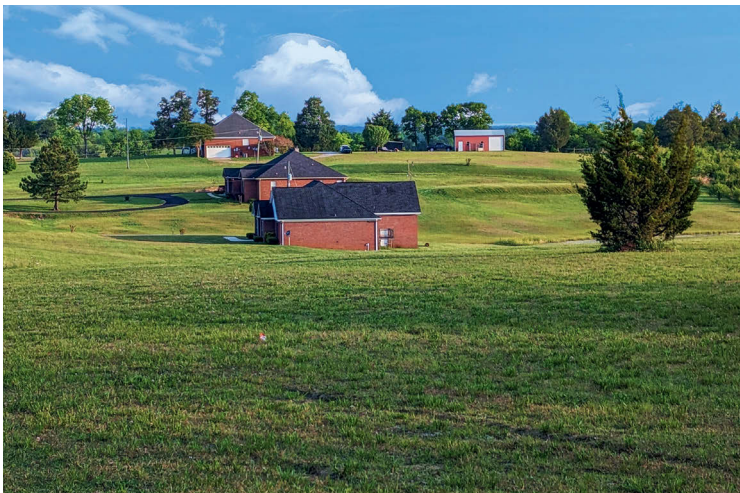
alternatives, the other intended effects of helping emerging insects won't be as impactful in areas already experiencing summer weather.

There are also downsides to No Mow May. Some landowners will never move beyond this step. The landowners who are partaking in No Mow May are also creating more attractive habitat for some wildlife that will only be cut down in June. This means their nests, territories, and even the organisms themselves can be destroyed when the area is mowed. Killing wildlife is the exact opposite of the program goals, which has led to some valid criticism. It does not help that many of the people and organizations promoting No Mow May fail to engage with the next steps to help landowners plant more native plants and have less lawn. However, when the public is inundated with lawn-care commercials and status-quo symbols that harm our wildlife, No Mow May is a useful tool. When followed up with further engagement and explanation to create more pollinator and wildlife habitat, the program is often successful at meeting its goals.

So, if you are wondering if you should join in on No Mow May, the answer is that you probably already did and are now steps ahead of the program. But if, by chance,

LEFT: Yards that are left to grow up in May can attract mobile wildlife, like leopard frogs (genus *Lithobates*), that are then at risk when the area is mowed. This is problematic for homeowners who only want to engage with No Mow May and not take further steps to create habitat.

No Mow May attempts to engage folks with large, expansive lawns. If your property is in this state, then, yes, you should join in and relax in May. However, if your yard already has habitats and reduced lawn areas, mowing in May helps discourage animals from sheltering in vegetation that will be mowed.



your home has a monoculture of mowed grass, maintained by pesticide and fertilizer application, then yes. Yes! You should absolutely not mow in spring, sign a pledge to use herbicide only in the most dire of circumstances, and use this book to create wildlife habitat. Even if you are steps ahead, No Mow May is a great program to let your lawn-keeping neighbors know about, because they are the ones the program was designed to engage.

Native Plants Only

Quite often, gardeners and land managers are presented with some version of "grow only natives," which is important in large-scale conservation lands, but not as effective in urban and suburban environments. Prominent researchers like Dr. Doug Tallamy and members of his lab and research teams have reviewed data and estimate that a ratio of 70% native to 30% non-invasive is acceptable in gardens. So which option is right? The short answer is that there is no golden ratio—simply do what you can. There are many reasons to have non-native plants in our gardens, especially ones

A large population of native ferns grow along a rock outcropping. Although this landscape is 100% native plants, the biodiversity is low. Since this landscape is connected with other native habitats, it functions as part of the ecosystem. However, if a small garden duplicated this monoculture, it would have much less ecological usefulness.

that provide food for us, which improves food independence and security. In reality, each species responds differently to native and non-native plant-community compositions, as well as garden landscapes in general. Dr. Tallamy's suggestion—based on bird studies, his research, and a lot of avian-insect data—affords landowners some grace (which this author appreciates and thinks is reasonable).

Other researchers have investigated species-specific responses to habitat degradation, including invasive species displacement, urban expansion, and agricultural lands. The overall trend is that most species can tolerate some amount of degradation. Less common in the scientific literature are studies focusing on completely altered habitats, with no native plants (although some invasive species studies do this). In these studies, data show there are a suite of organisms that are very adaptable and do well in completely altered ecosystems.

The folks who promote 100% native plants, no exceptions, are often trying to promote the best habitat for wildlife communities but fail to recognize any of the nuances discussed in chapter 1. Most of the more prominent people known for ardently promoting native-only plantings do not have advanced degrees in ecology, wildlife, or related fields. Instead, they came into native gardening from a less science-based background and are repeating ideas without understanding the data. This doesn't mean that only folks with degrees are right; it is just to point out that most of the scientists who look at data are saying wildlife communities can survive with some non-natives and a majority of native plants. Another point to consider is that these same advocates focus on removing lawns and non-native gardens but not ripping out driveways, knocking down sections of houses, or removing sheds (and there are many reasons not to). All of these non-garden objects are not native habitat, just like lawns, and if we include them in the native plant cover, we cannot reach 100%.

Part of this messaging also comes from a desire to prevent the arrival of new invasive species, which is a very real problem, and many invasive plants are escaped

Vegetable gardens, important for many folks, improve food independence while decreasing demand for long transports of food to stores. Yards have to work for both humans and wildlife.

An urban landscape in Oklahoma City, Oklahoma, filled with walls, cement, bridges, vehicles, and landscaping. Many native plants have been integrated into this landscape, which is arguably much better habitat than the channelized, cement-covered urbanscape it once was.

garden plants. The term *invasive species* has a specific definition in conservation and was legally defined by President Bill Clinton via an executive order. Although many gardeners misuse the term for aggressive natives and non-native plants alike, invasive species are non-native to the region and have been introduced by human actions, and their presence causes economic or environmental harm. Some states have listed native species as invasive because they do economic harm, but the proper legal term is *noxious* for native plants. In North America, a species can be both native and invasive. This is because once outside its native range, a species can spread and negatively impact the environment. There are also areas where the same species is simply non-native but does not escape or cause harm. Some of the folks who focus on 100% native also confuse a species' native range with being native to a political boundary, like a state or even a country. A great example is the California Fan Palm (*Washingtonia filifera*), a species that is native to springs in the Southwest deserts and widely sold. It has become invasive in every state it is native to and in many other regions of the world. However, this plant is often labeled "native" when sold by growers in states where its range does occur. As more plant species are propagated in horticulture, there is a risk for new invasive species to escape, but that risk won't be stopped by a small percentage of people adhering to 100% native.

In addition to the messy application of the term *native*, the concept of 100% native-plant landscapes tends to have two huge and incorrect assumptions. The first is that planting native plants creates native habitat for all wildlife. However, planting native plants only creates habitat for a few species and could take decades to centuries

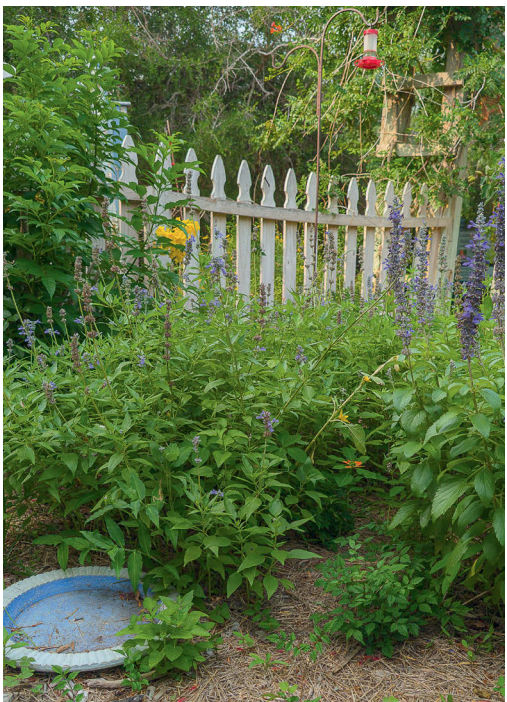
A native prairie installation with mowed paths. The local area is managed for only native plants, but adjacent properties have a variety of non-native species.

to create the missing resources many animals need. Similarly, many folks confuse native plant percentage or biomass with habitat and do not consider the other resources animals need for their life cycles. This assumption also ignores the fact that our gardens will always be unable to support the same abundance and diversity of wildlife as a natural area of the same size connected to healthy ecosystems. Our gardens, as well as restored areas, are missing important feedback systems, succession, and interactions that occur in natural, historical environments. A handful of these missing components are described in chapter 1, especially the sections on bears, American Bison, and Elk. Plant communities are interlinked with wildlife, including large herbivores, mesocarnivores, fungi, bacteria, and all of the other species not found in our urban/suburban environments. The absence of so many wildlife species interferes with resource creation, nutrient cycling, microhabitat formation, and plant succession. Many of these resources and how to include them in landscapes are discussed in chapter 2.

The second assumption is that the native-plant landscapes are equally accessible to wildlife and are the equivalent of habitat in non-urban environments. Rather often, folks ignore the fact each landowner's landscape is limited by size and by being isolated from wildlife populations. Our landscapes and the areas that animals need to traverse to find habitats we create include cement, roofs, 3-D structures, fences, and new dangers, and they lack overall habitat diversity. A variety of studies have shown that more mobile animals can establish in newly created habitat like rooftop gardens in Chicago, Illinois. However, less-mobile animals, like toads, snails, salamanders, and flightless insects, will not be able to establish there on their own.

Let's take a hypothetical neighborhood that follows the advice to only landscape with native plants. However, their designs might typically only use 20 native plant species. Although they would achieve 100% native biomass in planted areas, the areas would have poor habitat compared to the natural biodiversity. Areas around the plantings include houses, driveways, roads, and other structures that take up

ABOVE: A suburban park with isolated garden beds that are filled with non-natives and separated by lawn. Even if these beds were filled with native plants, these areas are not equally accessible from the nearby landscape. In urban areas where concrete and asphalt separate gardens, yards are further isolated from the ecosystem and too disconnected for many wildlife to utilize.



A landscaped garden with native flowers for the region of Texas where it is located. Although more natives could easily be used, this design is an improvement from a non-native garden design and includes key resources like a hydration disc and nectar feeder.

space and create barriers for wildlife. Depending on the density of houses alone, the landscaped area will only be a small percentage of the neighborhood, which could never have 100% native plant coverage; in many cases, it would be extremely hard to reach 70%.

This is all to say that having more native plants in your garden correlates to having more insects and other wildlife that can get there. There is no golden ratio of native plants to wildlife. Each species has a different threshold for what it can use as habitat. Furthermore, adding more non-flower resources for habitat to our native-plant landscapes will help species have higher success in completing their life cycles. Fortunately, studies in Chicago on rooftop gardens documented various species of native bees, illustrating that some insects can navigate our less-hospitable landscapes.

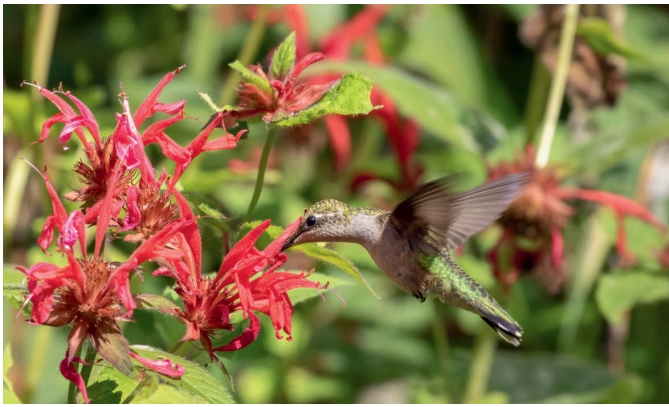
Plants: Wild Types, Varieties, and Cultivars

Finding native plants at nurseries can be very difficult. Even more difficult is finding plants grown from locally sourced seed, let alone the desired species to build your landscape. When native flowers are available, most often gardeners are offered a measly selection of native plants that are also intermixed with cultivars and varieties instead of wild types. As more and more data are collected, it is clear that native species are preferred by pollinators, varieties are usually equally preferred (sometimes more preferred, sometimes less), and cultivars often fail to attract the same abundance and diversity of pollinators. There are also a plethora of examples in conservation (from both plants and animals) showing that local ecotypes are important for the continued health of regional populations. Selecting native, local species is important for pollinators as well as the surrounding plant community.

A local nursery with dried wood pieces, nativars (naturally occurring forms or varieties of a species), and cultivars (generally bred for specific characteristics in captivity or crossbred with sister species).

Native species are also sometimes called *wild types* or *straight native*, suggesting that the plants are from natural, wild populations, but those labels do not mean it is of local origin. A *variety* is a naturally occurring mutation or sub-population of the plant that has a specific characteristic. This includes "weeping" varieties, flower and foliage color morphs, and overall growth form. The term *cultivar* refers to plants that are carefully augmented, sometimes over many plant generations. Some cultivars are crosses between the native species and one or more sister species; others are selectively bred for a mutation that may occur in the wild or be artificially induced. Most often, cultivars are asexually propagated, which means they are clones, with the same genetic plant being sold across its range and beyond.

When it comes to building habitat in our gardens, it is impossible to understand all of the interactions a single species will have. However, some prominent interactions are more easily understood, including natural variance and the reproductive success of populations, the ability to survive weather conditions, and pollinator and herbivore interactions. Locally adapted populations of a plant are more fit for the environment that occurs there, because the genetic lineage has successfully survived past droughts, exceptional rain events, heat waves, harsh winters, and so on. Another way to think about this is to look at a species' range. Instead of trying to figure out what environmental parameters it can survive in, we can look at the edges of the range to figure out which environmental parameters it cannot survive. If we look at a range in this way, it is easier to understand local adaptations. For example, in North America, a population on the southwestern extent of the range usually has less severe winters, hotter and drier summers, and longer periods of drought between rain events compared to populations in the northeastern extent of the range. Therefore, the plants in the southwest likely won't have the cold tolerance of the populations in the northeast, and the northeast populations won't have the drought and heat tolerance of the southwest population. So, if a company is selling plants they sourced from the northern extent of the range across the species' range, many of those plants at the opposite end of the range likely won't survive extreme weather years without assistance. However, those plants should still fill the same roles in pollinator and herbivore interactions. On a population scale, the introduction of plants from different regions poses out-crossing problems for ecoregion types with unknown ramifications at this time. In other words, populations have different stressors that they have evolved to survive, creating localized genetic differences that can make other populations less fit (e.g., cold-intolerant populations from the southern extent of a range could cross with northern-extent populations and reduce their cold tolerance). These problems concern many conservationists, which has led to protest and prevention of the commercialization of some rare, threatened, or endangered plants.



ABOVE LEFT: A *Calliopsis subalpina* bee sits on a Chocolate Daisy (*Berlandiera lyrata*), a native plant that smells of chocolate.

ABOVE RIGHT: A Ruby-throated Hummingbird (*Archilochus colubris*) visits a Scarlet Monarda (*Monarda didyma*), a native plant that has a few cultivars.

Cultivars pose new potential problems in landscapes that researchers have yet to understand. We do know that there are cases where cultivars interact differently with wildlife compared to wild types. Crop plants, for example, are often cultivars that were bred for taste. Herbivores, like aphids and deer, prefer some plant cultivars over the wild type. There are also known issues with plant cultivars that are bred for more showy flowers (often called "double"); for example, they simply provide less pollen for native bees. "Double flowers" occur when a mutation turns the stamens (pollen-producing structures) into petals. Such a mutation of the flower immediately reduces the amount of pollen the flower produces. There are even extreme examples of horticulturalists selecting flowering plant cultivars that are not attractive to bees to appeal to landowners who want to garden but are allergic to bees. In the horticultural trade, most cultivars are not studied beyond their ability to grow and produce the desired characteristic they are bred for. This means that pollinator and herbivore interactions are unknown, and invasiveness and reproductive success are unknown, as is their overall ecological impact. Because cultivars most often do not fill the ecological role of their original species and the above-listed unknowns, it is best to avoid cultivars whenever possible and to plant wild types and local varieties.

Pollinator Plants

The term *pollinator plant* is applied to a broad range of plant species, and generally with no explanation. What makes a plant good for pollinators? The easy answer is

that any plant that benefits a pollinator species is a pollinator plant. However, the degree of benefit and the number of species that feed on the plant can be used to rank plants in terms of their benefit to pollinators. Pollinators rely on plants in a few different ways. Most pollinators need to feed on nectar and/or pollen, with a few exceptions where pollinators use flowers for hunting or thermoregulation. Some pollinators also need host plants to feed their young, as we see with many insect groups, including butterflies, moths, and various beetles. This means that some plants are labeled pollinator plants because they provide ample food for pollinators, either nectar or pollen, and some plants get the label because they are a host plant for a pollinator species.

Flowering species like milkweed are larval hosts for a few different pollinators, including Monarch butterflies (*Danaus plexippus*), Queen butterflies (*D. gilippus*), Uunexpected Cycnia moths (*Cycnia inopinatus*), and milkweed beetles (genus *Tetraopes*), while also providing copious amounts of nectar for pollinators. Since this genus of plants provides food for many organisms and supports some species' entire life cycle, milkweeds are often ranked as great pollinator plants. Other plants often ranked "good" that provide copious amounts of flowers and support some insects' complete life cycle include sunflowers (genus *Helianthus*), coneflowers (genus *Echinacea* and genus *Rudbeckia*), Trumpet Vine (*Campsis radicans*), and bee balms (genus *Monarda*). Confusingly, some plants are considered good pollinator plants solely due to the number of blooms they produce or the length of time they produce flowers. For example, Eastern Redbuds (*Cercis canadensis*), cherries (genus *Prunus*), and goldenrods (genus *Solidago*) all produce prolific blooms, but only for a short amount of time. In contrast, dandelions (genus *Taraxacum*), lantana (genus *Lantana*), bee balms, and various sage species (genus *Salivia*) are considered good because they produce blooms through most of the growing season. In contrast, many plants that are important for a small group of pollinators are often not labeled a pollinator

An American Goldfinch (*Spinus tristis*) on goldenrods (genus *Solidago*), great pollinator plants that provide nectar and pollen.

plant. Examples include sand mats (genus *Euphorbia*) that support a variety of fairy bees (genus *Perdita*), gourds (genus *Cucurbita*) that feed squash bees (genus *Peponapis*), and yuccas (genus *Yucca*) that mostly provide food for yucca moths (family Prodoxidae).

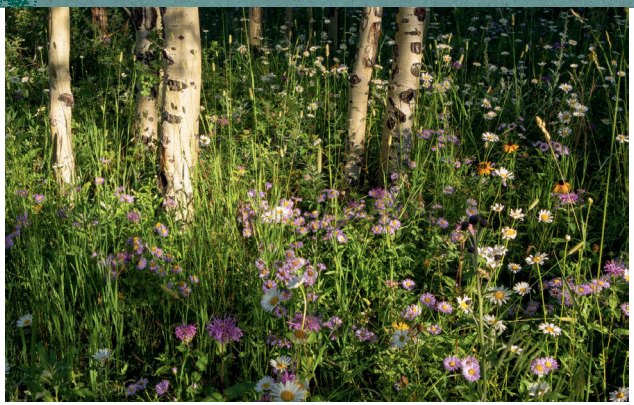
Because of the different ways plant species can be ranked in terms of being a pollinator plant, it is important to make sure the plants you choose as pollinators meet the needs of the habitat you design. Butterfly and hummingbird habitats, for example, often include flowering plants that won't support many bee species. This is due to the fact that bees are an oddity compared to other pollinators, because they feed pollen and nectar mixtures to their young, as well as consuming pollen as adults, along with nectar. Most pollinators—including bats, hummingbirds, butterflies, beetles, flies, wasps, and many other insect groups—primarily feed on nectar as adults. Nectar is the sugary liquid secreted by nectaries, which are glands on a wide range of flowers (and some stems). Flowers produce nectar to attract pollinators, so that pollen can be attached to the animals and then carried to another plant to assist with plant fertilization. It is important to know that flowers sometimes cheat the system; that is, some specimens provide much less nectar than other plants of the same species. Nectar cheats are part of the reason some gardeners notice pollinators not visiting a plant known to attract pollinators. Likewise, some specimens produce more than average amounts of nectar, which is valuable in small habitats. This range of nectar production is one of the problems with plant varieties available at garden centers, where they were selected for their bloom size or color, but not necessarily their ability to support pollinators. Flowers also modify how much nectar they produce based on

A pollinator garden with native and non-native plants that function as host plants and flower producers.

A Ruby-throated Hummingbird (*Archilochus colubris*) nectaring on a red bloom advertised correctly as a pollinator plant.

growing conditions; stressed plants usually produce less nectar than plants growing in comfortable conditions.

For pollinators, the amount of nectar a flower produces is just as important as how the nectar is presented. Hummingbirds, bee flies, and hawkmoths can access nectaries in long-tubed flowers like Cardinal Flower (*Lobelia cardinalis*), Coral Honeysuckle (*Lonicera sempervirens*), mock vervains (genus *Glandularia*), phloxes (genus *Phlox*), and Trumpet Vine (*Campsis radicans*). Short-tubed flowers—like bee balms (genus *Monarda*), Devil's Bouquet (*Nyctaginia capitata*), lantana (genus *Lantana*), and larkspurs (genus *Delphinium*)—have flower shapes that allow many butterflies, long-tongued bees, and moths to access their nectar. In contrast, many disc and ray flowers in the sunflower family (Asteraceae), large-cup flowers common in the cactus family (Cactaceae), and some flowers in the dogbane family (Apocynaceae) provide nectar to insects with shorter tongues, including short-tongued bees, bats, mantises, umbrella wasps, spider wasps, and flies. Some plants, like Desert Willow (*Chilopsis linearis*), Texas Sage (*Leucophyllum frutescens*), and various beardtongues (genus *Penstemon*) have flowers with shapes that allow some pollinators to crawl into the flower to access nectar. Conversely, plants that are not great nectar producers include most grasses (family Poaceae), docks (genus *Rumex*), yuccas (genus *Yuccas*), gourds (family Cucurbitaceae), and nightshades (genus *Solanum*). Table 2 provides a list of some North American native plants that are great nectar producers and are beautiful in the garden.



An area seeded with a pollinator mix fills with flowers. Often, these seed mixes are filled with non-native flowers.

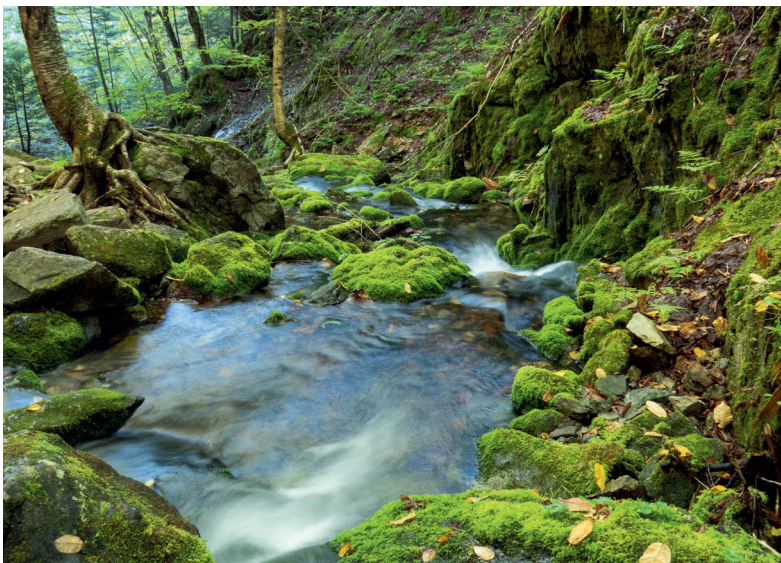
TABLE 2 Nectar-Rich Flowers That Are Great for Non-Bee Pollinators

COMMON NAME	SCIENTIFIC NAME
APOCYNACEAE FAMILY	
Climbing milkweeds	*Funastrum* spp.
Milkweeds	*Asclepias* spp.
Milkweed Vine	*Cynanchum laeve*
ASPARAGACEAE FAMILY	
Red Yucca	*Hesperaloe parviflora*
ASTERACEAE FAMILY	
Dotted Gayfeather	*Liatris punctata*
Firewheel	*Gaillardia pulchella*
Joe-Pye weeds	*Eutrochium* spp.
Mistflowers	*Conoclinium* spp.
Spanish Gold	*Grindelia ciliata*
Sunflowers	*Helianthus* spp.
Tahoka Daisy	*Machaeranthera tanacetifolia*
CACTACEAE FAMILY	
Prickly pears	*Opuntia* spp.
CONVOLVULACEAE FAMILY	
Bush Morning-Glory	*Ipomoea leptophylla*
Tievine	*Ipomoea cordatotriloba*
FABACEAE FAMILY	
Buttonbush	*Cephalanthus occidentalis*
Prairie clovers	*Dalea* spp.
FOUQUIERIACEAE FAMILY	
Ocotillo	*Fouquieria splendens*
LAMIACEAE FAMILY	
Bee balms	*Monarda* spp.
Cedar Sage	*Salvia roemeriana*
Salvias	*Salvia* spp.
MALVACEAE FAMILY	
Turk's Cap	*Malvoviscus arborea*
Narrowleaf Globemallow	*Sphaeralcea angustifolia*
ONAGRACEAE FAMILY	
Scarlet Beeblossom	*Oenothera suffrutescens*
PLANTAGINACEAE FAMILY	
Beardlip Penstemon	*Penstemon barbatus*
Beardtongues	*Penstemon* spp.
POLEMONIACEAE FAMILY	
Standing Cypress	*Ipomopsis rubra*
VERBENACEAE FAMILY	
Mock vervains	*Glandularia* spp.
Vervains	*Verbena* spp.

CONCLUSIONS

Our understanding of the natural world has changed drastically in the past few decades, and it will continue to change as more data are collected—that is how science works. As we learn new information, it is important to consciously evaluate our ways of thinking to unlearn the ideas that have been changed. Creating habitat for wildlife is all too often focused on native plants, an approach that comes with the assumption that wildlife can find what they need from there. However, it is clear that planting native plants is only a part of creating wildlife habitat. Furthermore, ideas presented in this book illustrate how much change has occurred in our natural environments in the past few centuries and how those changes affect what we perceive as healthy habitat. So we must actively adjust our understanding of what healthy habitats are and how best to create them in unnatural settings.

Keeping the major concepts of this book in mind while planning small-scale conservation projects, like gardens, will produce drastically different habitats than planting only native plants. Habitats are supposed to move throughout the landscape over time. This occurs through succession, disturbances, weather events, and animals. All landscapes in North America have been affected by modern actions, including the removal of species, introduction of invasive species, massive earthworks, pollution, the removal of indigenous peoples, and climate change. Many animals are responsible for creating microhabitats for other organisms, and their removal from our neighborhoods leads to imbalance and requires corrective action. Such action includes trimming, mowing, weeding, soil disturbance, removal of overpopulated animals, re-creating shelters and burrows, and refreshing resources.



A wonderful natural creek worth emulating in the right garden. Areas like this are filled with microhabitats that support a diversity of wildlife.

A wonderful wildlife garden in Cameron, Texas, designed and maintained by the Little River Basin Master Gardeners. The space is gorgeous and filled with shelters for birds, lizards, toads, and insects.

Lastly, remember to evaluate spaces from the target species' point of view, making sure to consider life cycles, shelters, and seasonal needs. Take the time to apply the concepts learned in this book to your overall region as well as garden projects. Also, be creative. These ideas are introductory and should be expanded upon, integrated into new ideas, and improved with your imagination. Additionally, engage with community groups, local policies, and parks departments to help them better manage lands. Together, we can make a difference and truly improve our neighborhoods for wildlife and ourselves.

Integrating and Pairing Microhabitats and Processes

Throughout the sections, many techniques and examples are provided to illustrate application in gardens. However, many ideas can be integrated together. Damp soils and leaf litter can be incorporated to irrigated garden beds as mulch, next to ponds, under rocks, and below gutter spouts. Wood resources can be integrated into borders, provide shade, function as walls and ceilings in burrows and dens, and work as trellises and nesting resources for bees. For gardens that are mostly starting from zero, it is important to take the time to plan garden beds, borders, irrigation, paths, ponds, and sun exposure and to couple each item with the needs of target wildlife. This can greatly reduce the effort needed to provide microhabitats and resources to support species throughout the year.

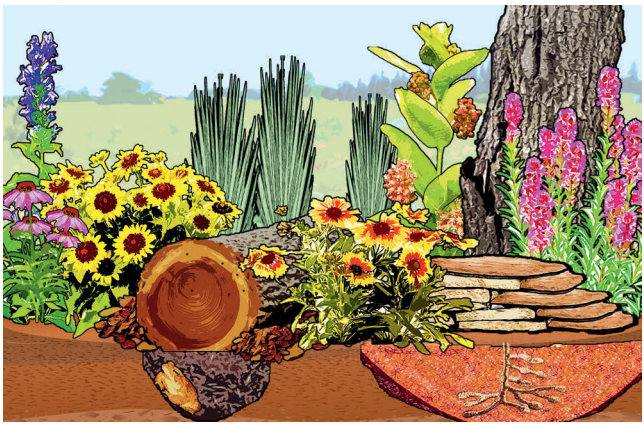
A naturally occurring pairing of resources with pools and runs of a stream with deep crevices and shelters used by various amphibians and reptiles.

A wildlife pond installation that was not paired with other crucial resources for wildlife. Shelters, soils, and pollinator plants would improve this installation with better aesthetics and provide a more robust habitat.

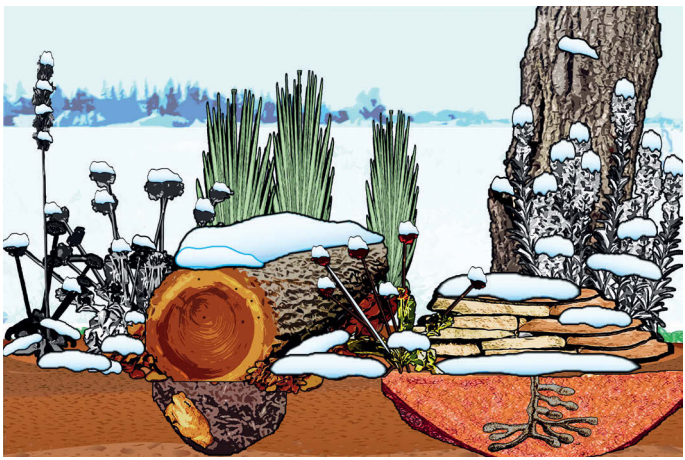
When designing areas, even single garden beds, consider whether small and medium-size shelters can be incorporated into raised beds, ponds, stonework, or minor topography. While selecting plants, find out which animals they support beyond the target species. For flying insects, consider how the design affects flight and whether insects and even birds can easily fly between plants or under the canopy, or if they can only fly out in the open above or beside plantings where they are exposed to predators. Think about which animals might rely on the space during each season and what resources can easily be provided. Once you have made a solid plan, do one last review to see if any of the major microhabitats—like loose soils, damp areas, mulch pits, stone shelters, and ground-level water dishes that may not be needed for target

wildlife but could be used by non-target species—can be added. For some landscape designs, there will not be many options, but it is always worth taking a second look.

For areas already designed that simply need some upgrades, evaluating areas from the perspective of your target wildlife will help in identifying missing resources. Some resources may be easy to provide by trimming plants, exposing soils between taller vegetation, amending a few areas of soil for nesting, and adding simple shelters. Rarely does it make sense to conduct major overhauls of gardens intended for wildlife, but if major projects are warranted, make sure to keep the disturbance as small as possible to keep wildlife safe. Providing temporary shelters, food, and water may be necessary for projects that impact over half of the area at a time. If heavy machinery or tree removal is involved, make sure to reach out to local wildlife rescues prior to starting to avoid animals being accidentally injured.



An illustration of above- and belowground resources that can be worked into small spaces. Areas in the soils can be amended in and around surface features as well as plants to provide sheltering resources for animals.



Understanding the spaces where wildlife overwinter is important. This diagram shows above- and belowground features, including how snow may fall around an area.

Application for Large Acreages

Every concept presented here can be scaled up into larger properties, including conservation spaces and reseeded restoration areas. Key resources for smaller animals, presented in chapters 1 and 2, should still be incorporated into landscapes, especially acreages that have suspended plant succession or that have simply removed many of the important non-flower resources.

Unlike the smaller areas of suburban neighborhoods, multi-acre projects can also plan and allow for areas to undergo successional cycles. However, it is important to also rely on larger animals to carry out some of the key processes absent from most neighborhoods. For large-animal care, rely on experts and organizations for keeping them healthy, not this book. There are a few other resources large acreages can offer: sand and mulch piles, placed a few hundred feet away from turtle ponds and creeks for nesting; larger dens and artificial caves for wildlife; soil cuts for nesting bees; and standing, large, dead snags for insect habitat, woodpeckers, and bats. There are also funding opportunities through federal, state, and private organizations to enhance

A large pasture with different vegetation-management areas.

A large property with mowed areas, fence lines, and robust ecosystems surrounding the landscape, which will benefit from habitat-creation projects.

large acreages for rare, threatened, and endangered species. Take the time to reach out to local extension offices or field offices to connect with resources.

Engaging Neighbors with Design: The 30% Rule

In many neighborhoods, native plant designs are likely to be few and far between. Luckily, our gardens do not have to be only native plants. A good rule to follow is that up to 30% of the landscape can be non-native. To better appeal to neighbors, carefully placing some of the more stunning, colorful native plants in plain view of onlookers can help win folks over. Likewise, using one or two non-invasive non-natives that neighbors are accustomed to can also help—but make sure to use plants that cannot escape. There are many different ways to strategically use native and non-native plants in a landscape to appeal to neighbors and provide habitat for wildlife. Keep in mind that using plants that can be trimmed and tidied or utilizing stunning designs instead of wildscapes will appeal to folks accustomed to lawns and hedges while also supporting an incredible amount of biodiversity.

For example, a border of petunias or impatiens near the sidewalk adds an intense, organized, familiar burst of color for onlookers. Native plants can be intermixed or planted right behind these familiar plants. This helps neighbors associate the nearby native plants with beautiful, intentional landscapes. Using horticultural plants that are known to be used by pollinators and eaten by wildlife also supports biotic diversity. Even if the selected plants do not provide great forage, like Sweet Potato Vine (*Ipomoea batatas*) and Purple Heart (*Tradescantia pallida*), vegetation creates cover and structure that wildlife can at least seek refuge in. Other habitat resources for wildlife can be included around non-native plants as well.

A different approach to consider is incorporating plants common in the landscapes of your neighborhood. Many yards have a plant or two in common. In some

A classically beautiful landscape, complete with garden beds and statues. A design scheme like this, which is then filled with as many native species as possible, illustrates how to use native plants.

A trimmed-up garden using native trees, nativar grasses, flowers, and a commonly used non-native Russian Sage (*Salvia yangii*) in the front.

communities, boxwoods and junipers are widely used to create hedges and topiaries. These shrubs can also provide nesting sites for birds and refuge for an assortment of invertebrates. Placing one or two in a focal area or front corner while also pruning it into a shape assists with connecting the surrounding landscape to what viewers understand as intentional landscapes. Although many wildlife gardeners are good at blocking out the opinions of others, using our yard to connect with neighbors is important and hopefully will convince them to take action.

Seasonal additions can also be integrated into a landscape. Early-spring flowers, like daffodils and tulips, can be planted near later-emerging herbaceous plants and under deciduous trees and shrubs. Late-fall additions can include growing groups of corn, placing pumpkins, and even incorporating a horticulture evergreen to decorate for winter. There are many ways to use our gardens that will appeal to people and wildlife. The better we can integrate wildlife habitat, human safety, and natural processes in an aesthetically pleasing way, the faster we can convince neighbors to move away from chemical-drenched lawns and sterile yards.

Encouraging local parks to landscape for habitat is another way to engage the community. Beautiful, nature-inspired landscapes can provide habitat and inspire visitors to create their own.

EPILOGUE

No garden should incorporate all of the processes discussed in this book. Selecting a few of the regionally specific processes, tailoring them for a limited number of target wildlife species, and adding in as many of the resources feasible for the size of the garden will create a robust habitat. When you follow certain practices—careful planning, goals to replicate natural processes and absent animals, adherence to landscape design theories, and upholding local ordinances—habitats can be robust and the envy of your neighbors. Lastly, always give yourself and others patience and grace, because there is a lot to learn and so much that is simply not known. Ecosystems are ever-changing chaos that have found balance between stressors and disorder. They are impossible to fully comprehend, so even the most ardent, ecologically trained, natives-only gardener is making mistakes, creating problems, and unaware of gaps in their own knowledge. It is this author's hope that your garden will prosper, fill with wildlife, and bring you (and your neighbors) joy.

A small botanic garden's pollinator habitat with gorgeous infrastructure, native flowers, and non-invasive plants. Farther into the garden, beds are filled with only native plants. This introduces visitors to gardening with native flora instead of rewilding.

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GLOSSARY

Abiotic. Non-organic or non-living factors in the environment.

Arid region. Area that receives less than 25 inches (64 cm) of rain, typically in seasonal periods.

Bug snug. Conservation tool that stacks small branches and leaf litter vertically to provide shelter for animals, mainly insects.

Burrow. Excavated opening in soil created by an animal. Burrows can vary in diameter and length, and regularly function as shelters for animals that did not create them.

Cave. Underground opening that extends deep enough for animals to use as shelter.

Colonize. To establish a population.

Community. Multi-species grouping of organisms based on the area where they coexist.

Conservation. Practice of restoring and managing areas with the goal of protecting habitats and the species within them.

Crevice. Crack or opening in an impermeable surface that can fill with soil or be used as shelter by animals.

Cultivar. Variation of a species generally bred for specific characteristics or crossbred with sister species.

Decay. Breakdown of organic matter and release of nutrients.

Deep burning. The most severe fire type; it kills most plants, including canopy trees. The fire also consumes organic material of all sizes above and within the topsoil layer and replaces it with white ash and charred organic matter. There is complete canopy kill, leading to the establishment of a herbaceous plant community.

Desert. Dry ecosystem with less than 10 inches (25 cm) of rain on average annually.

Diapause. Period when development is paused.

Disturbance. Event that causes a change in resources.

Early succession. Herbaceous, full-sun plant community that establishes after a disturbance; can include young woody plants, annuals, and herbaceous perennials.

Ecoregion. Defined area based on plant dominance, hydrology, and geology.

Ecosystem. Area that encompasses more than one habitat.

Enclosure. Area to keep animals in.

Endangered species. Species that is likely to go extinct without management.

Ephemeral. Short-lived, and usually seasonally dependent.

Establishment. Successful development of an organism or population that reaches a point where it can persist and reproduce.

Eusocial. When organisms of the same species have some level of labor division or sharing but not to the extent where members form castes, like workers.

Exclosure. Area or barrier that prevents some animals from entering an area.

Forest. Vegetation community with trees and more than 25% canopy cover.

Habitat. Area consisting of living organisms and non-living (abiotic) physical environmental features that are required for a species to complete its life cycle.

Habitat degradation. Reduction in quality of an area that negatively affects the ability of organisms to persist.

Hibernaculum (plural: hibernacula). Area used by a species during its hibernation period.

Hibernate. To pass long periods of time in a dormant state, typically with reduced biological processes.

Host. Organism fed upon by another organism; includes larval food plants and insects fed upon by parasitoids.

Host plant. Specific plant supporting the larval stage of an insect.

Instars. Distinct larval phases between hatching and pupating (or a mature form in incomplete life cycles), demarked by the shedding of skin.

Invasive. An aggressive, colonizing, non-native organism that arrived through human movements and outcompetes native organisms. President Bill Clinton provided a legal definition under Executive Order 13112.

Larva (plural: larvae). Developmental form of an animal that does not resemble the adult form.

Late succession. Community that establishes when disturbances that kill off the plant community are absent. Can also apply to the later stages of a plant community during the transition into the next stage of succession.

Light fire. Burned area where the tree or shrub canopy is mostly unaffected, while aerial stems and herbaceous vegetation, including surface litter and mosses, can be scorched. The organic layer of the soil and underground stems are left largely intact, and charring is limited to a few millimeters' depth.

Managed area. Area overseen by humans with practices to promote species or vegetation communities.

Mesopredator. Predator that also regularly preys on other predators; sometimes called a mesocarnivore.

Microclimate. Abiotic conditions of a smaller area within a larger region.

Nativar. Naturally occurring variation of a plant species, including color morphs and growth forms.

Native. Organism that evolved in an area or arrived without human assistance after 1600 C.E.

Natural areas. Spaces of land or water where development is reduced, including abandoned lots, golf courses, city parks, and wildlife refuges.

Natural enemies. Parasites, parasitoids, and predators of a species.

Nectar. Sugary liquid produced by many flowers and by extrafloral glands in some plant species.

Nest. Structure built or excavated by an animal to support and protect eggs, young, or itself.

Nursery log. Log or branch in late-stage decay that creates microhabitats that enable seedlings to establish.

Overwinter. To survive the winter in any manner, including hibernation, diapause, or being active.

Parasite. Organism that feeds on a host, usually without killing it.

Parasitoid. Organism that feeds on a host animal, usually leading to the death of the host.

Plant community. Grouping of multiple plant species that occupy an area.

Pollinator. Animal that carries pollen from one plant to another, facilitating plant reproduction. Typically, pollination occurs when animals seek nectar, but they also use flowers in other ways, including collecting pollen and sheltering in a part of a plant to stay warm.

Pond. Area of water that persists long enough for aquatic organisms to carry out portions of their life cycle.

Pupa (plural: pupae). Intermediate, usually quiescent, form of an insect; in insects with complete metamorphosis, the pupa exists between the larval and adult stages.

Pupate. Action of an animal as it turns into a pupa from its larval form.

Refugia (singular and plural). Space where organisms can escape some of the dangers present in the landscape, including climate.

Scorched vegetation. Vegetation in a burn area that did not burn but was affected slightly with leaf loss from heat, either lightly toasted or singed.

Seasonal. Temporary and usually dependent on a time of year, but not necessarily an entire climatic season.

Semi-arid region. Area that receives up to 20 inches (50 cm) of rain (this is 10 inches/25 cm more rain than deserts) and has long periods with no precipitation.

Senesce. To grow old; wither.

Shrub. Woody, perennial plant, usually with multiple stems growing to a height of between 6 inches (15 cm) and 6 feet (2 m) in semi-arid regions and 20 feet (6 m) in wetter regions of North America.

Shrubland. Vegetation community with at least a shrub layer.

Silviculture. Managed production of tree species for lumber or goods.

Snag. Standing dead wood.

Soil. Upper layer of ground, typically with nutrients to support plant life; comprised of organics, clay, sand, and silt.

Soil depletion. Removal of nutrients through either consumption by organisms or being dissolved in solution and leached.

Succession. Change in a plant and wildlife community due to maturation of plant species and colonization of new organisms.

Surface burn. Fire that chars and scorches understory vegetation; twigs and the organic soil layer burn up, and larger logs are charred. Some canopy cover is killed, but most survives. Most fire-management strategies target this type of burn.

Threatened species. (1) Species likely to become extinct. (2) Legally protected species that could become endangered without management.

Tree. Plant growth form that reaches more than 20 feet (6 m) tall or that, in arid regions, has a main trunk and woody growth that is more than 3 inches (7.5 cm) in diameter at approximately 4 feet (1.2 m) in height.

Unburned areas. Areas within a burn that flames have missed, leaving vegetation unaltered and with no clear effects caused by heat from the flames.

Vegetation community. Group of living plants in an area.

Woody. (1) Hard plant growth. (2) Texture of a material that resembles wood (sometimes used in descriptions of mushrooms).

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